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Electric Steel as a Test of a Great Corporation.

In these days when great corporations are subjected to acid and basic tests from many possible and some more impossible viewpoints, ranging from most intricate interpretations of the Sherman law to the simple, sweeping, autocratic distinction between good and bad trusts, this journal, as a plain engineering journal, likes to say a word about the greatest trust of all—the U. S. Steel Corporation—in the Nietzsche spirit of Jenseits von Gut und Böse.

The past hard winter with its innumerable broken-rail accidents has emphasized that it is plainly the business of the iron and steel industry to find means for making better rails. It was but logical that the American Iron and Steel Institute, in which 90 per cent of the iron and steel industry of this country is represented, should, at its recent meeting, deviate from its old policy of devoting all its time to commercial matters and welfare work, and should take up the serious discussion of some of the burning technical problems. What can be done to make better rails? Mr. Wm. R. Walker's paper on electric steel, published in full on page 371, was the answer.

To appreciate the scope and importance of this paper, the position of its author must be understood. Mr. Walker has been in the steel industry almost from boyhood on—as a chemist, in charge of Bessemer and open-hearth departments, in charge of the South Chicago works, as general manager of the Illinois Steel Co., and now in charge of all metallurgical improvements of the U. S. Steel Corporation. He was one of the first American steel men to see the possibilities of the electric steel furnace. It was Mr. Walker's influence and advice which led the U. S. Steel Corporation to take up the electric furnace and to make large-scale experiments on the heretofore untried problem of making steel for large-quantity products, like rails, in the electric furnace. It was on Mr. Walker's advice that many hundreds of thousands of dollars have been spent by the Corporation in its three years of experimental work.

That this was true pioneer work is clearly shown by the one detail of the electrodes. The step from a 5-ton Heroult furnace to the 15-ton size was too big for the amorphous carbon electrode makers. Now their troubles are past. Amorphous carbon electrodes are now made which will not break and which are sold at a reasonable price. But it is significant that if they had been available before, it would have saved over \$150,000 on the single item of electrode cost for the Steel Corporation.

In view of all these facts, Mr. Walker's unostentatious paper—written with an almost extreme modesty, so characteristic of its author—really assumes momentous importance in its simple statement of the success of the experiment and of electric steel rails. It foreshadows a big future for the electric steel furnace. Clearly the South Chicago experiment was a necessity. But who could have made it, in view of the expense, but a very big corporation? And was it not the same with Gayley's dry-blast experiment?

Evidently for electric steel refining on a very large scale the ice has now been broken and the credit for this belongs to the U. S. Steel Corporation and Mr. Walker. Though it is but fair to say that when this issue is mailed, the famous Deutscher Kaiser works in Germany will have done even better by starting a 25-ton electric steel furnace.

Clearly a big corporation can assume, for the advance of civilization, some of the functions of Nietzsche's "Übermensch," when working along legitimate technical lines "jenseits von gut und böse."

Status of the Porphyry Copper Producers.

The Copper Producers' Association report for May 1, 1912, showed an increase during the preceding month in the stock of marketable copper in the United States amounting to 2,927,829 pounds, or a total of 65,295,386 pounds. This is the first report since September, 1911, to show an increase, and only the second since May, 1911. Thus, for nine months of the year preceding May, 1912, a marked decrease was shown in copper production in this country. In view of the improved condition of the copper market, and the coincidental publication of annual reports by the five big porphyry copper producers, a brief analysis of their status may be of interest. A year ago, when low prices and increasing production marked the copper industry, considerable apprehension was felt regarding the effect of the porphyry coppers, on account of their enormous rate of production and cheap cost of operation. To-day those companies are in a still more impregnable condition, and the full effect of their production probably will not be felt this year.

The following tabulation shows the total ore reserves on January 1, 1912, and the mill capacities of the various plants now fully or partly completed:

| | Mill Capacity, Tons per Day. | Ore Reserves, Tons. | Grade per Cent. Copper. |
|--------------------------|------------------------------------|---------------------------|-------------------------------|
| Chino | 5,000 | 54,970,646 | 2.24 |
| Miami | 3,000 | 18,232,000 | 2.58 |
| Nevada Consolidated..... | 8,000 | 40,853,371 | 1.66 |
| Ray Consolidated..... | 8,000 | 77,314,470 | 2.17 |
| Utah | 21,000 | 301,500,000 | 1.53 |

Nevada Consolidated is running at full capacity, but the others will not reach that point until later this year. Utah has completed the remodeling of only nine sections of its Arthur plant, and the other four sections will not be ready for operation until after the middle of the year. The Utah Magna plant, however, is prepared to run to its full capacity of 12,000 tons per day. Chino, Miami and Ray Consolidated mills are about ready for full production.

Chino commenced production in October, 1911, and Miami and Ray Consolidated in March, 1911. The first ore milled at these plants has not been of a grade or quality equal to that which is expected later. Considerable oxidized ore from near the surface has been treated, and it has been impossible to make a high recovery on this ore, or to reach the normally low costs which are anticipated. Irregular operation, due to the alterations and adjustments usually found necessary in new plants, also has added to the cost of copper produced at Chino. Below are given figures showing the production of copper and its cost at the various plants:

| | Copper, Pounds. | Cost per Pound, Cents. |
|---------------------------------|--------------------|------------------------------|
| Chino | | 10.00 |
| Miami (since March, 1911).... | 15,385,783 | 9.11 |
| Nevada Cons. (15 mo.)..... | 78,541,270 | 6.97 |
| Ray Cons. (since March, 1911) . | 15,721,520 | 10.75 |
| Utah | 98,436,224 | 7.87 |

At Chino the average yield for the period was 24.5 lb. copper per ton of ore. In January, 1912, on a yield of only 22 lb. per ton, in two sections treating 800 tons each per day, the cost was only 8 cents per pound, and it is expected that under normal conditions this will be reduced to 7.5 cents. Ray Consolidated also had a higher cost than will prevail this year, on account of shipping concentrates to El Paso. The reduction in cost which will result from shipping to the new A. S. & R. Co. plant at Hayden, Arizona, will amount to 1.5 cents per pound of copper. This will bring the cost down to about 9 cents, and it is expected ultimately to reach 8 cents.

Metallurgical results in the newer mills are showing an improvement over those obtained in the first porphyry mills, and likewise, the remodeled mills are showing a similar improvement. There is still much to be desired, however, in respect to percentage recovery, and it is only when the percentage loss is expressed in pounds of copper that a full realization of the enormous loss is gained. Thus the loss in the Utah mills approximated 40,000,000 pounds copper in 1911, which is more than the total recovery in the Miami and Ray Consolidated mills, as shown in the foregoing table. The achievement of milling rock at a profit when it contains only 1.5 per cent metal is worthy of all commendation, but apparently a still larger problem remains.

Miami apparently leads in percentage recovery, with Utah, Nevada Consolidated, and Ray Consolidated following. No figures are yet available for Chino. Of the Utah mills, the remodeled Arthur plant is proving superior to Magna in economy of operation and metallurgical results, the former showing 70.49 per cent. and the latter 69.28 per cent. extraction. Ray Consolidated has improved metallurgical results since publishing the report, and the recovery has been brought up to 70.32 per cent. on ore carrying 1.68 copper, when 1100 tons were treated per day in each section.

The cost of milling at the Magna plant of the Utah company was 40.06 cents per ton, and at the Arthur plant 48.01 cents. The latter high cost is ascribed partly to the fact that some of the old equipment was used during part of the year, and partly to intermittent operation. When the Arthur plant is fully remodeled and running at capacity, the cost will be lower than at the Magna mill. At Ray Consolidated the cost of milling was 81.6 cents per ton for the period given, but was reduced to 76 cents for the last quarter.

Notable reductions in cost were made by Nevada Consolidated, due to improvements. Increased tonnage was responsible for lowering concentrating costs 15.9 cents per ton, or 25.72 per cent. The cost of roasting was reduced 8.3 cents, or 12.71 per cent. per ton of concentrate. By burning California oil instead of coal, the cost of reverberatory smelting was lowered 63 cents per ton of charge, or 24.31 per cent. The reverberatory charge was increased from 223.5 tons per day

to 359 tons. Basic-lined converters of the Peirce-Smith type are being installed and will gradually replace the old acid-lined converters, which, however, have been run for some time with a basic brick lining.

The sixth big porphyry producer will enter the field this year, viz., Inspiration Consolidated, in the Miami district, Arizona. Preliminary tests show the probability of saving 75 per cent. in a concentrator of 7500 tons daily capacity. If this is realized, Inspiration Consolidated may add 75,000,000 pounds of copper per annum to the already great flood of metal now pouring from the five plants before mentioned.

Steel Production in 1911.

The official statistics of steel production in the United States in 1911, as recently presented, are of considerable interest. The total (steel ingots and castings) was 23,675,501 gross tons, against 26,094,919 tons in 1910, which was the record, a decrease of 9.2 per cent. A curious feature is that in four of the past six years the production has been more than 23,000,000 tons and less than 24,000,000 tons, while in 1908 the production was only 14,023,247 tons, while in 1910 the production mounted to the 26,094,919 tons just mentioned. The average of the six years was 22,600,000 tons.

A feature of the steel statistics which strikes the casual observer quite forcibly is that, for the first time in history, the "production of steel" exceeded the "production of pig iron," the 1911 figures being 23,649,344 gross tons for pig iron and 23,675,501 gross tons for steel. Of course, every one knows that the production of steel as commonly reported is not the production of steel in commercial form. Omitting 1908 as an off year, the production of rolled steel, weighed as rails, skelp, forging billets, structural shapes, wire rods, black plates for tinning, etc., averaged in 1906, 1907, 1909 and 1910, 77 per cent. of the production of steel ingots, excluding castings. The 1911 production of steel embraced 23,029,479 tons of ingots and 646,022 tons of castings, and applying 77 per cent. to the ingot production we have 17,700,000 tons as the probable production of rolled steel, and even adding the production of steel castings we have a total of steel in commercial form much below the 23,649,344 tons of commercial pig iron produced. The loss of 23 per cent. from the ingot to the rolled form is due in small part to the production of scale, which usually goes back through the blast furnace, and in very large part to the production of steel scrap, which almost invariably goes into the open-hearth furnace, though occasionally into the Bessemer converter. Thus we have material which passes twice over the ingot scales, so that the "production of steel" is really the record of the ingot scales, plus the production of steel castings. The statistics may be misunderstood, but as presented they are strictly accurate, for the American Iron and Steel Association says that such and such a number of tons of "steel ingots" was produced. That is true; the ingot is produced when molten steel is poured into the ingot mold and allowed to solidify.

Hitherto the increment in the production of steel ingots and castings over the quantity of pig iron used therefor has been less than the amount of pig iron used for purposes other than steel making, such pig iron being used for the manufacture of

iron castings and for puddling. In 1911 such appears not to have been the case, but probably it was, although to a less extent than formerly, for there is good reason to believe that a large tonnage of stocks existing at the beginning of the year were used during the year in iron foundries, so that the consumption in this branch of the iron industry was larger than the production. However, a general study of the statistics shows that the production of steel has been increasing more rapidly than the consumption of iron in foundries and iron puddling mills.

For but the second time in its history, the basic open-hearth steel industry lost ground, its output being 15,292,329 tons in 1910 and 14,685,932 tons in 1911. The other time was in the off-year 1908. In every other year a new tonnage record was made. From 1897 to 1910, thirteen years, the increase was from 1,056,043 tons to 15,292,329 tons. Relative to total steel produced, of course, basic open-hearth steel has gained every year, constituting 58.5 per cent. of the total in 1910 and 61.1 per cent. of the total in 1911.

Acid open-hearth steel has lost ground, both relatively and absolutely. The 1911 output was less than in eight past years, the earliest of those being 1901, which showed 1,037,316 tons, the 1911 production being 912,718 tons. The cause is obvious, for practically as good steel can be made in the basic open-hearth as in the acid, and from much cheaper raw materials.

The race of the processes for supremacy is now ended, and a resume may be of interest. In 1900 practically two-thirds of all the steel made was Bessemer. In 1908 the total open-hearth exceeded the Bessemer, but this was rather an empty honor, since the Bessemer production was much below its record. In 1909 not only did the total open-hearth production exceed the best production (in 1906) of the Bessemer process, but the basic open-hearth production alone did so, and now we have it that in 1911, 62 per cent of the steel was made by the basic open-hearth process and 66 per cent. by the acid and basic open-hearth combined, the Bessemer contribution being less than 34 per cent.

The crucible process has yielded in much the same manner as the acid open-hearth, the crucible steel production in 1911 being 97,653 tons, exceeded by ten previous years, the earliest of which was as long ago as 1899. The record crucible output was 131,234 tons, made in 1907, a year in which the total steel production was substantially the same as in 1911.

A comparison of basic pig iron, and basic open-hearth steel production in the past two years shows how great has been the increase in the use of the new processes, which use little or no scrap. In 1910 the percentage of basic pig iron produced to basic open-hearth ingots and castings produced was 61.5 per cent., and in 1911, 59.5 per cent., an average of 60.5 per cent. Prior to 1905 the proportion was generally less than 50 per cent. The works which use cold pig iron probably use nearly, if not quite, as much scrap as formerly, but the works which use direct furnace metal get along with relatively small quantities of scrap. It should be noted that steel produced by the duplex process is simply classified as basic open-hearth steel. The open-hearth furnace has the last word, the Bessemer vessel being merely an adjunct, regarded as of no more importance in fixing the character of the steel than the mixer.

Iron and Steel Division of the American Institute of Mining Engineers.

The Council of the American Institute of Mining Engineers, at its meeting on April 26, established an Iron and Steel Division to represent the interests of the Institute in the mining and metallurgy of iron and steel; its business to be in charge of the following Committee, upon which shall rest the responsibility of securing papers and discussions on iron and steel for the meetings of the Institute:

Charles Kirchoff, Chairman; Charles F. Rand, Vice-Chairman; Bradley Stoughton, Secretary (165 Broadway, New York City); John Birkinbine, James Gayley, Henry D. Hibbard, Henry M. Howe, Robert W. Hunt, Julian Kennedy, Charles K. Leith, Richard Moldenke, Joseph W. Richards, F. W. C. Schniewind, Leonard Waldo, William R. Webster, Felix A. Vogel.

The Committee has met and formulated plans for carrying out its intention of securing papers and discussions dealing with all phases of the mining and metallurgy of the ferrous metals, and to such an extent as will make the American Institute of Mining Engineers the foremost iron and steel association in America, useful alike to the theoretical as well as the practical iron and steel man. The following subjects have been suggested: geology, mining and preparation of ores; concentrating, nodulizing, sintering and briquetting; manufacture of coke and other fuels; refractory materials; blast furnace, bessemer, open-hearth and electric-furnace practice; the duplex process; treatment, physics and chemistry of iron and steel, including metallography, and a campaign has already been started to secure papers and discussions on: alloy steels, heat treatment of steel, the duplex process, the thin-lined blast furnace, fuel gas for open-hearth furnaces, ore concentration, manufacture of pig iron, mechanical charging of blast furnaces, gas producers, charcoal iron, electric furnaces, recent improvements in open-hearth furnaces and practice.

The Committee will use its utmost endeavors to bring the papers presented on iron and steel to the attention of all members qualified to discuss them, and to stimulate a continuance of the discussion until all available data and information of interest have been secured for the *Transactions of the Institute*.

The Present Status in the Propaganda for a Change in the Patent Law.

There is now a decided activity—almost too much of it and tending in too many different directions—to procure a practical result so much to be desired in the propaganda for a change in the patent law to which we have referred repeatedly in our last issues.

On April 15th and 16th a joint meeting of the representatives of various national societies of engineers and lawyers was held in Washington, D. C. The following societies were represented: American Electrochemical Society, The American Institute of Electrical Engineers, The American Institute of Mining Engineers, The American Society of Mechanical Engineers, The Chemists Club of New York, The American Institute of Chemical Engineers, The Inventors' Guild, The Patent Law Associations of Washington and Chicago, and The New York County Lawyers Association. There was a long discussion in which the legal element predominated. The only outcome of this meeting was a petition to Congress to defer action on the patent bills now before it and the recommendation for further conferences of delegates from the bodies represented at that conference and from similar bodies which shall be invited to participate.

Since then the most important development has probably been a message from the President of the United States to Congress which emphasizes the fact that, "the present laws of the United States were enacted in practically their present condition in 1870, before the development of the industrial conditions which

obtain to-day." Various criticisms of the present patent law which have been raised by different parties, are briefly reviewed.

The message concludes as follows: "Great care should be taken in any revision of the statutes relating to patents and patent rights not unduly to interfere with vested interests which have been properly created under the existing laws, or to impair the efficiency of a system from which so much benefit has been derived by the country. I am of the opinion that a careful study of the patent laws should be made by a commission of qualified persons appointed for that purpose with instructions to report such revision of those laws as may be necessary to harmonize them with the best thought and needs of our time; and I therefore recommend the enactment of a statute authorizing the President to appoint a commission to investigate the present state of the patent law and to report what, if any, changes or amendments should be made to conform that law with modern conditions and acquirements." The message of the President was referred to the Committee of Patents.

New bills on patent law have been introduced in Congress and the interesting hearings on the original Oldfield bill have been continued. When they are completed we intend to give a concise analysis of the arguments brought forward by the different parties at these hearings.

Among the distinguished engineers who testified at the hearings were Mr. H. Ward Leonard and Dr. L. H. Baekeland.

The Right of Employer and Employee in Questions of Priority

Last year (our Vol. IX, page 457, September, 1911) we gave an account of a decision in a U. S. Patent interference case between Mr. D. E. Parker and Mr. G. F. Brindley which went deeply into the legal right of employer and employee in questions of priority of invention.

The decision was in favor of G. F. Brindley, to whom the priority of invention was awarded. He figured in the case as the junior party and as Mr. Parker's employer (as the representative of the Niagara Electro Chemical Co., or the Roessler & Hasslacher Chemical Co.).

The case was appealed, but on appeal the examiners in chief of the U. S. Patent Office have now confirmed the former decision in sweeping fashion.

The decision, which is signed by Messrs. T. G. Steward, Frank C. Skinner and Fairfax Bayard, as examiners-in-chief, is herewith given almost in full:

"This is an appeal by the senior party and patentee, Parker, from a decision of the examiner of interferences awarding priority of invention to the junior party, Brindley."

"The question is one of originality, for both parties are claiming the same embodiment of the invention as their reduction to practice. The invention was embodied in practical form during the month of May, 1905. Parker filed his application on May 18, 1906, and obtained a patent, No. 909,017, on January 5, 1909. Brindley filed about a month later than the date of this patent to Parker, or on February 17, 1909. Parker claims that he, and not Brindley, conceived of the main plan of the invention and that his disclosure to Brindley eventuated in the aforesaid embodiment of the invention.

"At the time the invention in controversy was brought into being, Brindley was the works manager and Parker was the machine-shop foreman of the Niagara Electro-Chemical Company. Brindley's period of service with this company extended from August, 1895, when the company was organized, until May 1, 1906. Parker entered the employ of the company on March 28, 1904, and remained the machine-shop foreman until November 16, 1905.

"Although it was during the period of Parker's employment that the invention was reduced to practice, it is con-

tended, on behalf of Brindley, that certain things which were done prior to the date of Parker's employment constituted material steps in the evolution of the invention. Parker, in his capacity of foreman, superintended the actual construction of the apparatus in which the invention was embodied, but the fact of this supervision is of little weight in the determination of the controversy, since, whether Parker was the originator of the invention or not, Parker would, in any event, have carried into effect the plan which the company adopted.

"Brindley and Parker undoubtedly stood in the relationship of employer and employee, for Parker was subordinate to Brindley and being so was bound to carry into effect any orders given him by Brindley.

"It will be observed that, as above indicated, Parker obtained a patent before Brindley filed his application and that the date of Brindley's application was upwards of four years later than the date of the reduction to practice, which occurred in May, 1905, and upwards of three years later than the date (May 18, 1906) of Parker's application.

"Although, under ordinary conditions the fact that the senior party to an interference has obtained an antecedent patent places upon the junior party a heavy burden of proof, yet it would seem to be true that in a case like the one at bar, in which a question as to the origin of the invention is to be determined, a conclusion that the junior party is the only one of the two interferents who is an inventor at all, may be reached without giving any especial weight to the fact that the junior party filed a belated application.

"In the present case, the fact that Brindley and Parker, respectively, bore the relation of employer and employee, is sufficient, we believe, to offset any presumption of originality that may be deduced from the fact that Parker is a patentee. But whether or not this is true in the broad sense, there is no reason to doubt the soundness of the proposition if coupled with the qualification that, as in the present case, the employer was the first to seek the desired result, as well as the first to devise and experiment with means to the end, which, in some form, appeared in the final embodiment of the invention. It is admitted by Parker that Brindley contributed certain of the ideas which resulted in the reduction to practice, but these ideas, it is claimed, involved nothing new and patentable and, therefore, are to be disregarded.

"We are not, in this controversy, dealing with the individual elements of the combinations expressed in the various counts of the issue, but are considering combinations which, while made up of a number of elements, are entities which, for the purpose of the interference, cannot be separated into their constituent elements."

"As we have already intimated, the employer, Brindley, will be presumed to have made the invention if he had in view the object sought to be obtained thereby, as well as means corresponding in a general way to that which was eventually found to be adequate for the purpose.

"The invention in controversy had its origin in the desire to produce and market fused peroxide of sodium, to which the Niagara Electro Chemical Company has applied the term "oxone." The Oxylithe Company of France had been marketing a preparation called "oxylithe," which consisted of compressed peroxide of sodium. The "oxone," or fused peroxide of sodium, was to be manufactured as a competitor of this "oxylithe" and, hence, the officers of the Niagara Electro Chemical Company were anxious to produce it on a commercial scale. The first experiments were made at Perth Amboy, New Jersey, by one Philipp, a research chemist of the Roesler & Hasslacher Chemical Company. Philipp's first report is dated January 16, 1904, and this, as will be observed, is prior to any date claimed by Parker for conception, and prior to the date, March 28, 1904, when Parker entered the employ of the Niagara Electro Chemical Company. It is satisfactorily established by the record that the term "oxone" was for the first time used in a letter addressed to Brindley on March 9,

1904, and so, it appears, that prior to the time when Parker became associated with Brindley the desired product was not only given a name, but that experiments were begun for its practical production.

"We do not deem it important to review herein the history of the various experiments that were conducted during the course of aforesaid experimentation, for the details of the various apparatus that were used during this period are fully set forth in the decision of the examiner of interferences, and in the briefs of the respective parties.

"In our view of the case, since it is clear that Brindley first devised or used means corresponding to some of the elements of the issue, while seeking to attain the desired end, which was the production of "oxone," and Brindley was Parker's employer, such contributions as may have emanated from Parker must be regarded as being merely ancillary to the main plan of the invention. We consider this to be the law, even if the apparatus first used by Brindley did not comprehend the whole invention, for we are determining whether it was the contributions of Brindley or those of Parker, neither of which involved the entire structure of the counts of the issue, that led to the production of that combination. Brindley was the first to seek the result, the first to initiate the experiments, and the first to direct attention to certain elements which eventually became features of the new and patentable combination in which each of those elements, by being merged into that combination, became possessed of a new attribute.

"In these cases of originality between employer and employee, the presumption is rightfully in favor of the employer who is by experimentation seeking to attain a particular result, the reason for the presumption being due to the confidential and close relationship of the parties which renders it difficult to later determine to what extent the thoughts of the employer may have been impressed upon the employee's mind. The employee may honestly believe that a vital suggestion originated with him, when, as a matter of fact, the idea originated with the employer and had been revealed unconsciously in some forgotten conversation.

"The following cases are in point: *Milton vs. Kingsley*, 75 O. G., 2193, 7 App. D. C., 531; *Miller vs. Kelley*, 96 O. G., 1039, 18 App. D. C., 163; *Gedge vs. Cromwell*, 98 O. G., 1486, 19 App. D. C., 192; *Gallagher vs. Hastings*, 103 O. G., 1165, 21 App. D. C.; *Kreag vs. Geen*, 127 O. G., 1581, 28 App. D. C., 437; *Larkin vs. Richardson*, 127 O. G., 2394, 28 App. D. C., 471.

"We, furthermore, think that Brindley, the employer, ought to prevail, notwithstanding his delay in applying for a patent, for the record shows that he promptly filed his application after the patent to Parker was issued.

"A ground of appeal is that the examiner of interferences erred in not making a recommendation concerning public use of the invention for more than two years prior to the date of Brindley's application. This is not an appealable question, and the appeal is dismissed as to this ground. Also, we decline to make a recommendation as to public use, since there appears to be no evidence satisfactorily showing that the use of the invention was public, although it is shown that the product was sold.

"The decision of the examiner of interferences awarding priority to George F. Brindley, the junior party, is affirmed."

The Western Metallurgical Field

Unwatering Leadville Mines.

Progress is being made in the project to unwater the mines in the Fryer Hill district, at Leadville, Colorado. In September, 1911, it was proposed to organize a company to install suitable pumping machinery to unwater a mining area which is now under water, but which is known to contain bodies of valuable ore. The plan was mutual in its proposed benefits, for the pumping company was to receive only a small royalty on ore actually extracted and treated as a result of the unwatering of the mines. In January, 1912, a communication was

sent to the owners of the property on Fryer Hill, notifying them of the proposition, and asking their support. This elicited such a general commendation of the scheme that further steps were taken to draw a suitable contract, binding the pumping company to install a pumping plant, and requiring the owners of the property to work their mines after the same were unwatered. These contracts were sent to the mine owners last month.

Inasmuch as the success of the project depends on almost unanimous co-operation of property owners, this feature has had to be considered in drawing the contracts. The following provisions are among the more important: If the owners of 95 per cent of the acreage in the district shall execute the contracts on or before the first day of August, 1912, the pumping company agrees to erect and place in operation on or before the first day of April, 1913, pumping equipment having a capacity of not less than 1000 gallons per minute. This equipment will be placed at the most advantageous point, perhaps at the El Paso shaft, and the pumping shall continue until the district shall have been unwatered to a level of a horizontal plane passing through the bottom of the El Paso, which is the deepest shaft in the district. Within thirty days from the time any property shall have been unwatered the owners shall begin work with five men for each 10 $\frac{1}{3}$ acres owned, and shall operate their mines so as to take out the greatest amount of ore practicable. If work is not so begun by the owners within thirty days of unwatering, the pumping company automatically secures a lease on the ground and may sub-lease it; but if the pumping company is unsuccessful in securing sub-lessees within ninety days, the property shall revert to the owners. From these provisions it will be seen that the success of the scheme depends on the activity of the mine owners, for if they do not work their mines the pumping project fails. The pumping company can be successful only in the event of continuous and successful mining. The district will either be a scene of great activity, or remain in its present dormant state.

The schedule of royalties decided upon is as follows:

| Value of Ore per Ton | Royalty |
|----------------------|---------|
| Up to \$5.00 | 5% |
| \$5.00 to \$7.50 | 6% |
| \$7.50 to \$10.00 | 7% |
| \$10.00 to \$12.50 | 8% |
| \$12.50 to \$15.00 | 9% |
| Over \$15.00 | 10% |

Several contracts have been signed, and the work of sending out the balance has proceeded as rapidly as the magnitude of the project would permit. It is hoped and expected that the idea will meet with approval, and that Leadville will experience a great revival as a result of this endeavor.

Vanadium and Uranium in Colorado and Utah.

Southwestern Colorado and southeastern Utah form the principal vanadium and uranium field on the North American continent. Owing to the isolation of this region and the desultory nature of the actual mining work which has been carried on by a number of small operators, it has been difficult to arrive at any exact idea of the magnitude of the industry. General information and unreliable rumor have credited the field with greater resources, production and profit than actually exist. As a consequence, the annual report of the Colorado Commissioner of Mines for 1911 is a welcome document, for it endeavors to give some sound facts concerning this part of the metallurgical field.

As stated in our issue for October, 1911, page 482, the only metallurgical plant in this district is that of the Primos Chemical Co., at Newmire, Colo. Here vanadiferous sandstone is treated at the rate of about 30 tons per day, producing iron vanadate which is shipped to Primos, Pa., for further treatment. Recently it has been announced that the Colorado Vanadium Co. has secured the old National mill at Sawpit, near Newmire, Colo., and will remodel it for the treatment

of vanadium ores. It is also known that the Vanadium Ores M. & M. Co., of Grand Junction, Colo., contemplates the erection of a plant at Grand Junction for the treatment of carnotite ores which the company owns in the Utah part of the field.

For the most part, however, the production of vanadium and uranium ore is shipped from Colorado and Utah to Pennsylvania and to Liverpool, England. The Colorado shipments from Placerville during 1911 amounted to 1515 tons of vanadium ore mined in Montrose county. The ore averaged 3.5 per cent metallic vanadium, and the average price paid f. o. b. cars at Placerville was \$70 per ton.

Not enough development has been done to determine the extent of the ore bodies, and practically all the ore mined thus far has been taken from lenses in sandstone strata which are exposed on one or two sides. The cost of mining is considerable, while the cost of exploration is still greater on account of the irregular thickness of the ore lenses.

Pittsburg-Silver Peak, Nevada.

The litigation in which the Pittsburg-Silver Peak property at Blair, Nevada, has been involved for about 12 years, seems in a fair way to be settled. The company received a favorable decision at the hands of the United States Court of Appeals in San Francisco over a year ago, but the case has been in the hands of the Nevada Supreme Court since that time. It is expected, however, that a decision will soon be rendered by the latter court, and since it is improbable that the case will be carried further, a favorable decision now is expected to end litigation.

The company is making a good record for low cost of operation and production, a late report placing total operating costs at \$2.70 per ton, which is exceeded by but few low-grade properties. The mill, in which recovery is made by amalgamation and cyanidation, is being equipped with a tube mill for regrinding coarse sand, and it is expected that this addition will reduce the time of cyanide treatment and increase recovery by about 1 per cent. The mill contains 120 stamps and is treating more than 500 tons per day, with a recovery of between 90 and 91 per cent. One tube will be tested on one unit of thirty stamps before the entire regrinding equipment is placed.

Mayday-Idaho Suit, Colorado.

The Mayday mine in the La Plata mountains, southwestern Colorado, has been a producer of wonderfully rich smelting ore since about 1904. Shortly after its development by A. E. Reynolds, of Denver, considerable attention was attracted to the district, with the result that the Idaho mine was developed by W. A. Stewart, of Cripple Creek, into a similarly rich producer of gold. Both mines continued to produce until December, 1910, when a suit was filed in the United States court by Reynolds, alleging that, owing to a faulty survey of a section line, he was entitled to considerable ground then claimed by the Idaho company. As both mines had proved good producers, the suit was contested and brought to a decision on April 22, 1912. The decision is favorable to Reynolds and the Mayday company, but an appeal will undoubtedly be taken to the United States Supreme Court. In the meantime the Colorado smelters are deprived of shipments of rich smelting ore, and the American Smelting & Refining Co. holds \$85,000, representing the net return from the last shipment made by the Idaho company prior to the filing of the suit. The disposition of this money will depend on the final decision in the case.

Company Reports.

The tenth annual report (1911) of the *United States Reduction and Refining Co.*, Colorado Springs, Colo., is not designed to inspire the stockholders with encouragement or hope for future profit from the company's operations. The Standard chlorination plant at Colorado City was closed at the end of the last fiscal year, and existing ore contracts turned over

to the Golden Cycle company. The smelter at Canon City is still idle, although a lease was granted to parties who intend, if possible, to re-treat the old slag dump for its zinc content. The only remaining activity of the company consists in the tailings cyanide plant at Florence, Colo., where the old dump of the Union chlorination mill is being re-treated by cyanidation. Even this plant is not proving satisfactory, and it is considered doubtful whether more than the plant investment and interest will be obtained from operations. The tailings plant was originally designed to treat by continuous decantation, but so much difficulty was encountered from various causes that the continuous decantation scheme has been abandoned, and the plant is run on straight sand-leaching principles. About 800 tons per day are being treated, and operations probably will cease by fall.

The seventh annual report of the *Nipissing Mines Co.*, Cobalt, Canada, for the year 1911, contains some interesting metallurgical information. A new mill for the treatment of first grade ore was started February 1, 1911, and is now treating the entire product of the mine. The process, which was devised by Mr. Charles Butters, consists in amalgamation in cyanide solution in a tube mill, where more than 97 per cent of the silver in the ore is recovered as amalgam. The residue then undergoes the regular cyanide treatment whereby an additional extraction is made. A refinery has been erected, and the entire product of the mill is shipped as fine silver. The cost of the mill and refinery was \$57,122, and the first year's operation has shown a substantial profit compared with shipping the ore to a smelter.

Careful experiments on low-grade dump ore run through the high-grade mill indicate that a good extraction can be made on the dump material by the amalgamation and cyanidation treatment, and that the net returns will exceed those obtained by the usual concentration methods. Consequently a mill to treat 200 tons per day is now in course of erection and will be started before the end of the present year. All ore will be transported to the mill by tramways, where the first-class ore will be removed, and the fine stuff treated in the jigs. The ore resulting from these operations will be sent to the high-grade mill for treatment. The balance will be crushed in cyanide solution by 40 stamps of 1500 lbs. each, pass through tube mills, amalgamated if found desirable, agitated and sent to a Butters filter. Precipitation will be by zinc dust, collecting the precipitate in a Merrill filter. The precipitate will be refined in the high-grade mill.

The Iron and Steel Market.

Market developments in the iron and steel trade in May were not of striking importance, there being simply a continuance of the strong condition established in April. Specifications against old contracts for finished steel products were heavy, and almost uniformly in excess of current output, so that the mills closed the month with more actual business upon books than at the opening of the month. Strictly new buying decreased, but this was to be expected in the circumstances of buyers generally being well contracted, in an advancing market.

The steel industry is operating now at almost full capacity. Many plants are operating at absolutely full capacity, but the showing as a whole is pulled down by the fact that in a few lines, particularly wire and pipe, demand is not sufficient to engage the full capacity. The production in steel is easily the heaviest on record, passing the previous high rate attained in the early months of 1910. Pig iron production, however, is materially below the record, as the merchant furnaces are operating at only about two-thirds their greatest previous rate. The country is making pig iron at the rate of between 29,000,000 and 30,000,000 tons annually, the best previous record having been about 31,600,000 tons, in February, 1910, while the pro-

duction from October 1, 1909, to April 1, 1910, was at the average rate of 31,000,000 tons. An increase in the merchant furnace rate is to be expected, and would probably have occurred before this had it not been that coke has reached a very high level and idle furnaces going into blast must as a rule contract at the high level, while the operating furnaces as a rule have old contracts made at much below the present level. A number of these contracts expire June 30th. To justify paying the higher prices current the blast furnaces require higher prices for pig iron, but the advancing tendency is not very marked and the experience of an actual scarcity may be required to adjust matters.

Railroad buying was relatively heavy in May. Several railroads purchased rails when their purchases made last winter had been assumed as sufficient to carry them through the season. Orders were placed in May for about 30,000 cars, against orders for only 40,000 cars during the preceding four months of the year, and the car shops enter June with more business on books than on January 1st, though at that time they were very well supplied through the burst of buying which occurred in the closing three months of last year.

New buying in steel products, outside, perhaps, of that involved in railroad material, is likely to be relatively light during the next few months, but the mills are so well filled with business that full operations for several months can be predicted with confidence.

Pig Iron.

There has been steady buying in most districts, though not for delivery far ahead. Southern iron has experienced a sharp advance since last report, on relatively light sales. Quotations are now as follows: No. 2 foundry iron, Birmingham, \$11 to \$11.50; delivered Philadelphia, \$15.25; f. o. b. valley furnaces, \$13.25; f. o. b. Chicago district furnaces, \$14.50; Bessemer, valley, \$14.25; basic, valley, \$13 to \$13.25. Ferromanganese has been advanced \$2.50 and the regular price for second half contracts is now \$48.50, Baltimore, while small lots for prompt shipment have been bringing from \$50 to \$60.

Steel.

The mills are well sold up on billets and sheet bars and are practically out of the market. Consumers are well covered by contracts, but are not getting entirely satisfactory deliveries. Quotable prices, which are largely nominal, are: Billets, \$20.50 to \$21, and sheet bars, \$21 to \$21.50, f. o. b. maker's mill, Pittsburgh; billets, \$20 to \$20.50, and sheet bars, \$20.50 to \$21, f. o. b. maker's mill, Youngstown. Wire rods are \$25 to \$26, Pittsburgh.

Finished Steel.

Prices have shown no important change since last report. The American Sheet & Tin Plate Company on May 17th advanced its prices on all coated tin mill products by advancing its minimum on tin plate from \$3.40 to \$3.50. On May 21 the National Tube Company reduced its discount on steel boiler tubes one point, making an advance equivalent to about \$2 a ton. The new card discount on 3½ to 4½ inch is 74 per cent, beyond which two extra fives are customarily given on large orders.

Current prices, f.o.b. Pittsburgh, unless otherwise stated:

Rails, standard sections, 1.25 cents for Bessemer, 1.34 cents for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.25 cents.

Shapes, 1.25 cents.

Steel bars, 1.20 cents.

Iron bars, 1.25 cents, Pittsburgh; 1.30 cents, Philadelphia; 1.20 cents, Chicago.

Sheets, blue annealed, 10 gage, 1.40 cents; black, 28 gage, 1.90 to 1.95 cents; galvanized, 28 gage, 2.95 to 3 cents.

Tin plates, \$3.40 to \$3.50 for 100-pound cokes.

The Non-Ferrous Metal Market.

Since our last report the non-ferrous metals have practically held the positions given at that time. Considerable activity has been noted in tin which is in an excellent statistical position. Lead has been the duldest of the metals, while the business in copper and spelter has not been unusual.

Copper.—Owing to the business transacted by second hands who had secured copper on speculation, the largest sellers have not done a large volume of business. European demand has been very light, and domestic consumption comparatively small. Prices are held up, however, and the last reports are, for Lake, 15¾ to 16 cents, and for electrolytic, 15.55 to 15.65 cents.

Lead.—Business has been unusually dull, but the A. S. & R Co. has maintained its prices at 4.20 cents, New York. Business has been transacted by other sellers at 4.15 cents. St. Louis market ranges from 4.02½ to 4.05 cents.

Tin.—The excellent demand for this metal has given it an unusually good position which probably will be held. Prices have gone as high as 46¾ cents, New York, for May tin, but at the last report this had fallen off to 45¾ cents. Higher prices may prevail.

Spelter.—Both buyers and sellers seem to have been content to transact little business, as the former were well supplied and the latter were not disposed to press sales. Later in the month some producers did cut prices and made sales at varying prices for future deliveries. The last quotations are 6.50 to 6.60 cents, New York, and 6.35 to 6.45 cents, St. Louis.

Other Metals.—Domestic producers of aluminium have raised their prices to meet those of Europe, and the prevailing price is 21 to 22 cents, New York. Business in antimony has been moderate, and prices are quoted at 6¾ to 8¾ cents for various brands. Quicksilver is steady at \$41.50 to \$42, New York, and \$41.50, San Francisco, for flasks of 75.

CORRESPONDENCE.

The Introduction of the Tube Mill into Metallurgy.

To the Editor of Metallurgical and Chemical Engineering:

SIR:—On page 266 of your May issue is an abstract of a paper read before the Canadian Mining Institute by Mr. Henry Hanson, in which credit is given to Dr. Ludwig Diehl for the first introduction of the tube mill in metallurgy.

I am confident that this is an error. The tube mill is an American invention and was first used for the fine grinding of ores in 1894, in the Moulton mill, Butte, Montana, owned by former Senator W. A. Clark.

New York City.

R. F. ARRÉ.

What is Steel?

To the Editor of Metallurgical and Chemical Engineering:

SIR:—Prof. J. W. Richards' definition of steel, "all varieties of usefully malleable iron" in your May number, page 266, is interesting to me because it is the first part of that which I proposed in 1908 and communicated to the American Institute of Mining Engineers, which was, "Steel is a variety of iron which at some temperature is malleable to a useful degree; it is made by a fusion-process, or when not so made is capable of being hardened to a useful degree." The distinction made that the malleability was useful, was, I believe, novel.

His definition can hardly be accepted, however, because of violence it does to established usage at each of its extremes. Wrought iron is entitled to its name and will keep it. At the other end of the line are Cocker steel plates used for wire-drawing, which are claimed to contain sometimes 2½ per cent of carbon or more, while some cast irons contain less. This prevents 2.2 per cent being proper for the upper limit of steel.

The need for scientific names for iron products, including those now called steel which will fit into the scientific classifica-

tion of iron and steel, is felt and acknowledged by all who have given the matter much thought. Instead, however, of extending or abridging the current meanings of the term 'steel,' would it not be better in order to avoid adding to the confusion now existing, that new scientific names be coined to designate different species, such as (1) usefully malleable iron, and (2) fused usefully malleable iron, and others? Such names might in time get into common use, the chance for which would be increased if they were short.

Prof. Richards calls it a false principle of classification to use the method of manufacture as a basis. Abstractly speaking this is true when the same product may be made by different methods, but when the product itself shows how it was made, as in this case, it may be permissible and more convenient to say that it was welded (wrought) or fused, than to describe it by the characteristics which welding or melting gives.

Plainfield, N. J.

HENRY D. HIBBARD.

* * *

To the Editor of Metallurgical and Chemical Engineering:

SIR:—Mr. Hibbard misses much of the point of my article "Steel." We both know and agree upon what is steel, we agree upon the facts, as they exist in the present arbitrary and illogical use of the term; there is no need of disputing that point.

What is needed is a resolution to use the grand, old, historic term in a consistent, logical, scientific way, and this can be done by the simple expedient of making *useful malleability* the one decisive characteristic of steel, distinguishing it from cast-iron. Under this proposed classification, wrought iron can keep its name, no one wants to take it away, but logically its malleability should class it as a variety of the broad class "steel." If "Cocker steel plates" used for wire-drawing, at the other extreme, are not usefully malleable (as I suspect is the fact), they are cast-iron, and not steel.

My proposition regarding the content 2.2 per cent. of carbon, was to use it only as a *supplementary* criterion, in case doubt existed as to whether the material was usefully malleable or not. I believe that a material with 2½ per cent. carbon should be called steel, *if it is usefully malleable*; and a material with 2 per cent. carbon should be called cast-iron if it is under no conditions usefully malleable.

My only object in proposing to broaden the term "steel" so as to include wrought iron within it as a variety, is to get theory and practice to agree upon a meaning of the term which is both logical and practical, acceptable alike to science and industry. Mr. Hibbard says in effect: Word the definition to correspond to present usage, and let it go at that. But that does not remedy anything, it does not improve matters one jot or tittle; as well try to reform a man by enumerating his bad habits—and stop there. What is wanted is some modification of the meaning to be attached to the term "steel," such as will end the inconsistencies of present usage and put the nomenclature on a logical, orderly and scientific basis.

We need to look forward a little, to lay straight foundations for future building. The term "steel" has changed its meaning within the last fifty years, from a reasonably definite meaning to a hybrid usage which, from the standpoint of a scientific classification is "neither fish, fowl nor good red herring." We agree that it cannot be forced back to its former limited but definite meaning. What shall we do? Stand forever deploring the unfortunate facts; or shall we, like master builders, find a simple way of straightening out the situation, grasp it, and on that basis reconstruct a classification that needs no apologist? If we can, by the one simple change I have proposed, achieve this much-desired rationalization of the term "steel," is it not worth doing? We should do it, for the sake of correcting present inconsistencies and of avoiding others that may easily and will surely arise unless some such step is taken.

J. W. RICHARDS.

Lehigh University, South Bethlehem, Pa.

The Installation and Use of Pyrometers in Steel Mills.

Equipment and Methods of Control at Illinois Steel Co.'s Works.

By C. S. GORDON.

The first practical pyrometer was devised in 1782 by Wedgwood, an English potter, for use in operating his kilns. He depended upon the contraction of clay at high temperatures for his measurements.

In the ceramic industry Seger cones having various degrees of fusibility are used. These cones have a tendency to curl over when certain temperatures are reached, but, of course, are valueless to show whether the temperature has fallen.

Fusion-point pyrometers have been used, making use of the known melting points of different metals and other substances. These were the first to enter into the manufacture of steel, the temperature of the blast furnace blast being measured by holding a rod of metal or other substance with a known melting point at a place where the blast would strike it. For instance, if a rod of pure silver would just melt, the temperature of the blast was known to be about 954° C.

The next class of pyrometer to enter into the manufacture of steel was the thermo-electric pyrometer, which is still being used for medium high temperatures (500 to 2500° F.), while for exceedingly high temperatures (2500 to 6000° F.) the radiating and optical pyrometers are being used.

The manufacturers of steel are to-day the most extensive users of the pyrometer for the measurement of high temperatures. In some instances the employment of pyrometers has advanced to such a degree that it has been necessary to employ a pyrometer expert and to establish a laboratory for the express purpose of repairing and standardizing the many instruments of the company.

The South Works of the Illinois Steel Company were the first to establish such a laboratory. This laboratory has been in operation since June 5, 1911, and is located in the main laboratory building of the South Works, South Chicago, Illinois. The benefits of the laboratory and of the knowledge of the man in charge have been extended to the several other plants of the corporation in the near vicinity, including the Gary Works, at Gary, Indiana; the Buffington plant of the Universal Portland Cement Company at Buffington, Indiana; the Joliet Works, at Joliet, Illinois, and the Milwaukee Works, at Milwaukee, Wisconsin.

This has resulted in a great saving of time and expense for the different plants, because through this section of the country there are no manufacturers of pyrometers, which would necessitate the shipment of all repairs to the Eastern cities.

The pyrometer is a very delicate instrument, and consequently should be handled with great care. In most cases the operator of a pyrometer does not realize the delicacy of the instrument, and, therefore, handles it as he would handle a more massive instrument. Then he wonders why he did not get results, or why the instrument is out of calibration, or why the thermo-couple is broken. The chances are ten to one that the instrument has not been properly handled; sometimes it is due to carelessness, but more often to ignorance.

The fact that an instrument is out of calibration may be unknown to the workman. He turns his readings over to the superintendent, who in turn figures out results which are incorrect. The superintendent may have seen the reading taken, which would make him positive that his results were correct.

Such an example came to the writer's notice only a few days ago. In one of the boiler rooms a pyrometer was being used for over a month for taking temperatures in the fire box of a gas-fired boiler and another pyrometer was being used to take the stack temperatures. Results showed a very high heat

efficiency. The writer had occasion to use the instrument which was being used under the boiler, and was surprised, on checking, to find its reading to be over 260° F. low at the point where it had been used in the previous tests, while a check of the pyrometer in the stack showed it to be reading correctly.

In the use of the thermo-electric pyrometer there are two sources of error which only about one operator out of ten can correct or even understand, and in many cases these errors may be as much as 250° F.

First, the error due to the cold-end temperature of the thermo-couple. In most cases the pyrometer is calibrated with a cold-end temperature of 77° F. (25° C.), which is considered the average inside atmospheric temperature. The millivoltage generated depends on the difference of temperature between the cold end and hot end or junction of the thermo-couple. Consequently, should the cold-end of the thermo-couple be at a higher temperature than that at which it was calibrated, the pyrometer readings will be low an amount equal to from 1 to 1/3 of the amount above the temperature at which the thermo-couple was calibrated, depending upon the alloys used for elements of the couple. This error may be corrected by changing the zero setting of the instrument or by adding the correction to the temperature readings.

Second, there is an error due to the temperature coefficient of resistance of the pyrometer. The thermo-electric pyrometer is nothing more than a low-resistance millivoltmeter. The resistance of the coil increases with rise in temperature, which reduces the amount of current flowing through the instrument, and this in turn reduces the temperature reading. This error averages from two to three per cent. for every ten degrees centigrade rise in the temperature of the meter movement.

The location of a pyrometer is a very important factor in obtaining correct results. It is important that the pyrometer be installed where the workmen can read the temperatures. This necessitates the installing of the instrument near the furnace or source of heat, which may mean in a building where the atmospheric temperature is very high. Under these conditions it is necessary to determine the temperature of the cold end of the thermo-couple and also the temperature of the instrument to obtain correct results.

In some instances the writer has seen pyrometers installed where, if the wind was from a certain direction, the instrument and the cold end of the thermo-couple would be at the same temperature as the outside atmospheric temperature. If it was a moderately warm day the results would be correct or nearly so, while if it was a very cold day the results would be from 75 to 100° F. high. Should the wind change to another direction the pyrometer and cold-end temperature of the thermo-couple would be heated by the warm air radiated from the several furnaces, bringing the temperature of the pyrometer and cold end of the thermo-couple to 150° F., which caused the results to be from 100° to 150° F. low.

It is such errors as the above mentioned that the large companies wish to reduce to a minimum. In the heat treatment of a large roll for steel mill work or in the heat treatment of a carbon-steel tool, 100° F. is an exceedingly large error. It is an error which might cost a company several hundred dollars.

The pyrometer expert of the Illinois Steel Company makes inspections of the different installations throughout the plants at least once every two weeks, instructing the operators of the instruments in their use and determining the correction factors. In some cases the location of the instrument has been changed in order that the correction factor might be more constant. Where the temperature of the meter or cold-end of the thermo-couple is exceedingly high or is variable through a wide range of temperature a water jacket is used. If several thermo-couples are used with one meter, the average cold-end temperatures are determined and the zero setting

of the instrument is adjusted to this temperature, making the meter reading as nearly correct as possible.

At the time of inspection the permanent installations are checked against a standard portable indicating instrument which is standardized before leaving the laboratory and again checked after being returned to the laboratory. With this system the different departments know that when they have a set of temperature readings they are correct.

Types, Makes and Uses of Pyrometers in Different Departments.

In the South Works of the Illinois Steel Company there are 46 thermo-electric pyrometers used by the **blast-furnace department** alone. Forty-four of these are Bristol combination sets and two are portable indicating instruments used for checking the combination sets. One of these is a Bristol instrument with a scale range of 1600° F., the other is a Brown instrument with a scale of 3300° F.

The Bristol combination set consists of a smoked-chart recording instrument and a Bristol switch-board-design indicating instrument connected through a switch-box to one thermo-couple. The switch-box contains a double-pole, double-throw knife switch for each instrument. To the cen-

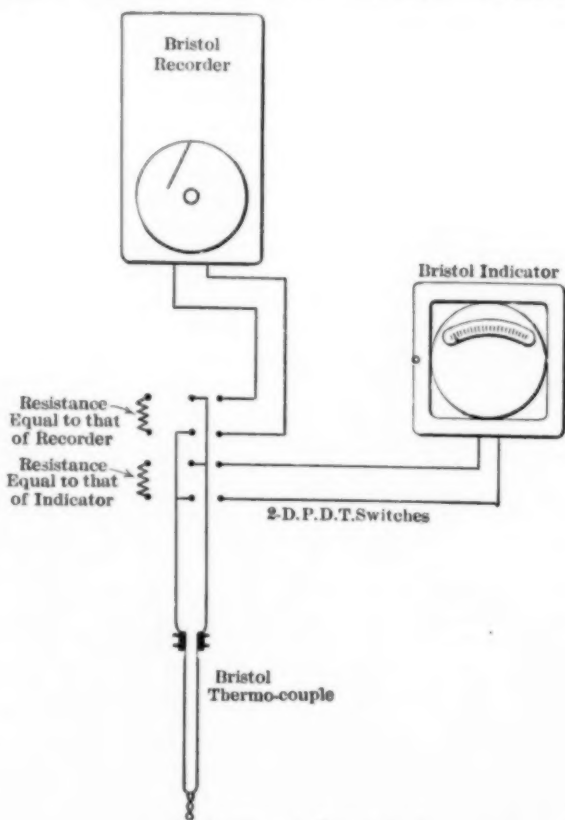


FIG. 1.—COMBINATION SET.

ter of these switches are connected the thermo-couple leads. A resistance coil is connected across one side of the double-pole double-throw switch, exactly equal to the resistance of the instrument connected to the opposite side. The purpose of this resistance is to compensate for the resistance of the circuit should the operator wish to cut out one meter or should it become defective. By reversing the switch the meter remaining in the circuit will register correctly.

The distance of the thermo-couple to the switch-box in some cases is as much as 200 feet, and that from the switch-box to the recording instrument 695 feet, and from the switch-box to the indicating instrument 220 feet. This makes a total length of lead from the thermo-couple to the recording instrument of 895 feet and from the thermo-couple to the indicating instrument of 420 feet.

The No. 12 flexible, rubber-covered duplex leads are all installed in wrought-iron pipe to protect them from fire and mechanical injury.

In the blast-furnace department the pyrometers are used for two purposes. First, for the measurement of the hot-blast temperatures, which range between the temperatures of 800° and 1200° F. The maximum average practice is 1150° F. and minimum average practice 850° F. In the installation of these pyrometers the thermo-couples are installed from the top of the blast-pipe and are protected by the use of a nickel protecting tube. The location is in the pipe between the hot-blast main and the furnace bustle pipe.

From this location of the thermo-couple the lead extends to a small brick building, known as the pyrometer house, located near the furnace stoves. In this building is located the switch-box containing the two double-pole double-throw switches. At the side of the switch-box is a dust-proof box containing the indicating pyrometer, which is for the use of the stove tender. A blackboard is placed near this instrument and every hour the temperature is tabulated. This is done in order that the superintendent or foreman may have a means of checking the temperatures read on the indicating instrument against those tabulated by the recording instrument which is located in the main blast-furnace office.

All the recording instruments are placed in a consecutive order on a large switch-board located in the main office, where the superintendent may at all times tell at what temperature the blast is being blown to the furnace.

Secondly, pyrometers are employed in the blast-furnace department for the measurement of the temperature of the top gas. Top gas is the name applied to the gas generated in the furnace. This gas is brought down into large chambers, known as dust catchers. The dust settles to the bottom of these chambers, where it is drawn out from time to time while the gas is piped off through large mains for use in the engine and boiler rooms. The pyrometer thermo-couple is located near the top of this chamber or dust catcher, being put in from the side. The leads extend down and across to the pyrometer house, as mentioned above, to the switch-box.

In this case the switch-box only is located in the pyrometer house, the indicating instrument is located at the foot of the charging elevator, where the workman operating the charging scale car may know the temperature of the top-gas. The top-gas temperature varies with the charging and ranges between 150° and 500° F. In this case the recording instrument is also located in the main office.

The indicating instruments are all of the Bristol switch-board type, Model No. 162, with the Weston millivoltmeter movement. These used for hot-blast temperatures have a range of 1600° F., while those used for the top-gas temperature have a scale range of 1100° and 1260° F.

The recording instruments used are all Bristol smoked-chart Model No. 137, with the Weston millivoltmeter movement. Those used for hot-blast measurements have a temperature range of 1600° F., while those used for top-gas temperature measurements have a temperature range of 1100° F.

The thermo-couples used are all the 1600° F. standard Bristol base-metal alloy couple with a bessemer-steel element against a nickel-copper-steel element generating about 60 millivolts at a temperature of 1832° F. (1000° C.) with the cold end temperature 24° C.

The next most extensive user of the pyrometer is the **metallurgical department**. This department requires instruments for measuring higher temperatures than any other department of the steel mills. The metallurgical department of the South Works has one Hoskins portable indicating thermo-electric pyrometer, type P. H., with a scale range of 1400° C., and one Hoskins recording pyrometer, thermo-electric, type P. R., scale range 2000° F. With these two instruments they have several types and lengths of the Hoskins nickel nickel-chromium thermo-couple, some being as much

as 15 feet in length. These long thermo-couples are used chiefly in the heat treatment of rolls, which are heat treated in the various mill soaking pits. One Le Chatelier recording pyrometer, thermo-electric with a platinum-platinum-rhodium thermo-couple, is used for laboratory work exclusively. One Keiser-Schmidt single-jewel type indicating thermo-electric pyrometer, with a Heraeus platinum, platinum-rhodium thermo-couple, scale range of 1600° C., is also used for laboratory work.

One Fery radiation pyrometer of the portable indicating instrument type is used for measuring temperatures which are too high to be measured by thermo-electric pyrometers or in such cases where it is impossible to take the temperature measurement with a thermo-couple. It is used for such purposes as the measurement of temperatures in open-hearth furnaces, temperatures about 1600° C., temperatures of molten metal coming from the open-hearth, temperatures of metal being poured into moulds about 1500° C., temperatures of reheated ingots for rolling about 1200° C., and for measuring temperatures of slag and molten metal at blast furnaces and Bessemer converters.

This instrument is also used for determining temperatures at the **electric furnace**, some of which are as follows:

Finished steel from electric furnace 1495° C.

Temperature inside furnace before charging 1300° C.

Temperature of charge of bessemer steel before charging furnace 1500° C.

Temperature inside furnace after running forty minutes 1425° C.

Slag skimmed from metal 1400° C.

Temperature of empty furnace just after pouring 1500° C.

The metallurgical department also has a Thwing radiation portable indicating pyrometer. This instrument is a fixed-focus instrument, suitable for quick reading of a hot-body, such as the temperature of a rail, or ingot or plate passing through the rolls.

They also have five Wanner instruments. These Wanner optical pyrometers are the most desirable instrument for use where it is impossible to use a thermo-electric pyrometer, because they are easily carried from place to place and are quickly focused. In many cases where a very accurate temperature measurement is desired both the Fery and Wanner are used and the average results taken.

Another department using a number of pyrometers is the **steam engineering department**. This department handles the general mechanical engineering tests of the plant. They have one Bristol quick-reading 3000° C. indicating pyrometer with three platinum, platinum-rhodium thermo-couples. This instrument is very seldom used by this department, but is kept on hand in good repair for emergencies.

Further there are three Bristol smoked-chart recording instruments with scale ranges of 1100°, 1800°, and 2000° F., respectively. At present these are being used as follows:

The 1100° instrument is kept in a first-class condition for general testing work.

The 1800° instrument is used in the pit of a waste-heat boiler located in the open-hearth plant. The waste heat from one of the open-hearth furnaces is used to operate a 200-hp. boiler. The temperature in the fire box range from 900° to 1200° F.

The 2000° instrument is used for measuring temperatures of the gas generated by the gas producers at the open-hearth plant. These temperatures are used in connection with the taking of gas analyses.

The **open-hearth department** also has two instruments of its own which are used for the same purpose, one a Bristol smoked-chart recorder scale, range 1800° F., the other a Bristol indicating pyrometer, scale range of 1600° F.

The steam engineering department also has a Bristol, portable indicating pyrometer, scale range 2000° F., and a standard portable, indicating Hoskins thermo-electric pyro-

meter, scale range 2550° F. This pyrometer is used as a standard for checking pyrometers installed throughout the plant and is made with an aluminum pot so that it will be light and easily handled. It also is calibrated with a rheostat so as to reduce to a minimum the error due to the temperature coefficient.

Some of the uses found for pyrometers by the steam engineering department are measuring fire-box temperatures under boilers, comparison of temperatures at different points in the fire-box, measuring stack temperatures, measuring waste-heat temperatures, measuring temperature of superheated air and gas-producer temperatures.

The **mechanical department** also uses two Hoskins pyrometers, both being used in the blacksmith shop. One is used for the determination of the critical points of tool steel and is known as a recalescent outfit. It consists of a Hoskins portable indicating instrument and a very small thermo-couple.

The critical point is obtained by clamping two samples of the steel over the twist of the thermo-couple and then heating it slowly. The needle of the meter will rise gradually to the decalescent point, at which it will hold for a few seconds; the sample may then be taken from the furnace and allowed to

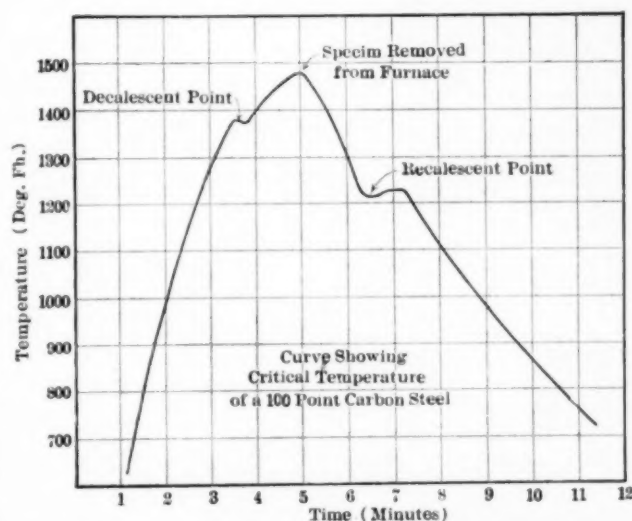


FIG. 2.—HEATING AND COOLING CURVE SHOWING CRITICAL TEMPERATURES.

cool; the needle will begin to drop, indicating the cooling of the sample, but at a certain point the needle will again hold for a few seconds before continuing to drop. This point is known as the decalescent point.

The critical point or decalescent point is a point necessary to know before perfect results can be obtained in hardening tools. It depends on the composition of the steel. If it is a pure carbon steel, this point depends upon the amount of carbon. If it is an alloy steel, it depends upon the amount of other metal and also the kind of alloy, but the average critical points vary between the temperatures of 1250° and 1450° F.

The second pyrometer of this department is installed at the hardening furnace, where it is equipped with a calibrated rheostat and thermometer so as to reduce the error due to temperature change of the meter, to a minimum. It is also equipped with a double-pole switch and several thermo-couples, one being used in the tempering furnace, a second in the oil bath used for drawing, and a third thermo-couple in a gas forge furnace.

The **chemical department** also uses a number of thermo-electric pyrometers in the laboratories. The most extensive use is for the determinations of carbon contents of steels, ferro-alloys, and graphite by the combustion method as described in Hoskins Bulletin No. 5. The thermo-couple is

placed in the furnace alongside the combustion tube containing the combustion boat of steel.

We find in use in the South Works of the Illinois Steel Co., at the present time 70 pyrometers of various makes, the resistance pyrometer being the only one which has not found its way into the steel mills.

Illinois Steel Co., South Chicago, Ill.

Radiation Pyrometry.

By G. A. SHOOK.

II. Theory of Radiation Pyrometers.

In the first paper published in the April issue of this journal, two important radiation laws were given, namely: the total-radiation or fourth power law, and the distribution law.

The working principles of the following two classes of pyrometers are based upon these two laws. In the first class, black-body temperature is determined by measuring the total energy, as in a Fery or Thwing pyrometer, which allows radiations of all wave-lengths to fall upon a sensitive thermo-couple connected to a direct-reading galvanometer.

In the second class, some particular wave length is used and the measurement of temperature is made photometrically by adjusting to equality two photometric fields produced by a standard source and the body to be measured.

The intensity of radiation is varied by cutting down the objective aperture, as in the Le Chatelier, or by a polarizing device, as in the Wauner, or by varying the intensity of the standard itself, as in the Holborn.

Total Radiation Pyrometers.

From a consideration of the Stefan-Boltzmann radiation law we have seen that the energy radiated by a black body is proportional to the fourth power of the absolute temperature, or

$$J = KT^4 \quad (1)$$

From this relation it is evident that a comparatively rough method of determining the energy radiated would yield fairly accurate results of temperature measurements. Now if the energy from an incandescent body falling upon a given area, could in some way be measured we could get a measure of the body's apparent black-body temperature.

However, this energy is very small, as one knows by experience, and therefore to get even a rough measurement of it requires very delicate and sensitive apparatus.

Since radiant energy is transformed into heat, whenever it falls upon any body, and since, moreover, the temperature of a body increases when heat is imparted to it, the rise in tem-

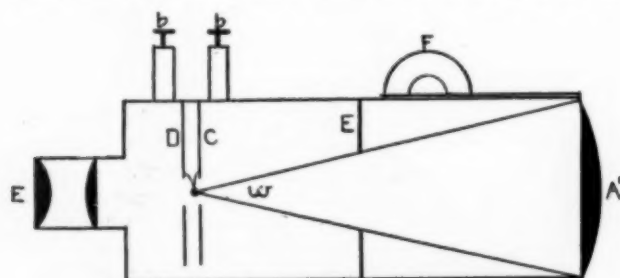


FIG. 1.—FERY RADIATION PYROMETER.

perature of a given absorbing body might be taken as a measure of the temperature of a radiating body. For example, we might blacken the bulb of an ordinary thermometer and put it in the path of the rays from some hot body. The rise of mercury in the thermometer would be proportioned to the fourth root of the absolute temperature of the hot body in question.

In the total radiation pyrometer used today, the radiant energy is concentrated by means of a lens or concave mirror upon a small metallic disc whose front face is covered with lamp-black. Some form of a sensitive thermometer such as an antimony-bismuth thermo-couple is placed in contact with the

disc. The thermo-couple is, in turn, connected to a direct-reading galvanometer.

The Fery radiation pyrometer is shown in detail in Fig. 1. Radiation from an incandescent body is focused upon a minute and sensitive thermo-couple *C*, by means of a lens *A*. In order to calibrate the pyrometer directly in terms of the Stefan-Boltzmann law, the lens should be transparent for all radiations and this is best effected by using a fluorite lens which for temperature above 900 deg. C. does not absorb an appreciable portion of the incident radiation.

F is a rack and pinion for focusing the radiation upon the thermo-junction. The screens *C* and *D* protect the junction from extraneous rays. The diaphragm *E* provides a constant-angle aperture, which is a necessary condition for the instrument to be independent of focusing. The thermo-junction leads are in turn connected to a galvanometer.

In making a temperature measurement the image of the incandescent object is focused upon the thermo-couple by means of the eye piece *E*, and care must be taken that the image is larger than the thermo-couple.

It is evident from equation (1) that if the galvanometer has a uniform scale and the temperature *T*₁ is known corresponding to a scale reading *R*₁, the temperature *T*₂ for any other reading *R*₂ may be found from the relation,

$$T_2 = T_1 \sqrt[4]{R_2/R_1}$$

When the limit of the scale is reached the calibration may be extended by means of a diaphragm placed before the objective or by shunting the galvanometer. In technical practice, however, a glass lens is used and the instrument is calibrated empirically against a black body whose temperature can be determined.

This instrument is also made with a gold reflector instead of a lens.

Fery has recently brought out a new pyrometer which is similar to the above, with the exception that the temperature is measured by means of a minute expansion spiral consisting of two metals with dissimilar expansion coefficients. This mechanical device renders the instrument more robust but does not admit of so great accuracy as the thermo-element.

In the Thwing pyrometer a long conical mirror is used and consequently a lens is not necessary. All of the rays falling upon the aperture of a conical mirror will ultimately reach the apex by multiple reflections from the side.



FIG. 2.—PRINCIPLE OF THWING RADIATION PYROMETER.

Hence, if a sensitive thermo-couple is placed at the apex, Fig. 2, it will obtain the same effect as it would if placed at the focus of a lens or concave mirror.

Within wide limits the indication of the instrument is furthermore independent of the distance from the hot body. The instrument, therefore, requires no focusing.

The thermo-couple is connected to a direct-reading portable galvanometer. This type of total-radiation pyrometer is remarkable for its ease of manipulation and sensitiveness.

The Bureau of Standards have quite recently been able to make extremely minute thermo-couples of antimony and bismuth by a very ingenious method. If a bank of these thermo-couples could be attached to the small heater of a radiation pyrometer, the sensitiveness would be considerably increased.

For instance, if a temperature of 600 deg. C. produces a deflection of about one-fourth the galvanometer scale in case of a single thermo-couple, then by using four couples in series the same temperature would produce a full scale deflection. This means that low temperatures could be measured accurately which is now impossible with this type of instrument.

Optical Pyrometers

Although this type of pyrometer is perhaps more useful in many ways than the total-radiation pyrometer, it is in theory somewhat more difficult. If properly analyzed, however, it will be seen that the essential parts of this instrument are not inherently new.

A photometer is an instrument for comparing *luminous intensities*. If a white opaque screen be moved to and fro between two lights until the illumination on both sides of the screen appears the same, the *luminous intensities* of the two lights bear a certain definite relation to each other.

The luminous intensity of a light source depends upon the *brightness* or *intrinsic intensity* and the extent of the luminous surface. For example, if one looks at a small area of an incandescent sheet of metal, it will appear just as *bright* as an area many times as great, but, of course, the larger area will illuminate a photometric screen to a much greater degree than the smaller area.

An optical pyrometer is essentially a photometer which compares the intrinsic intensity, for a particular color, of a hot body with some standard lamp, and which is calibrated in terms of temperature instead of candle-power.

In the case of an ordinary photometer, the two photometric fields which are brought to equality, are illuminated by diffused light, such as is transmitted by a ground glass, so that unless one always examines the same area, which would be impossible in pyrometry, the photometer would not give a true measure of the brightness or intrinsic intensity of the body in question.

Suppose, for example, that we had a large sheet of incandescent metal at a constant uniform temperature. One square foot of this surface would evidently give only one-half as large a reading upon a photometer as an area 2 square feet in extent.

Now since the brightness varies with the temperature, in optical pyrometry we are concerned with the brightness and not with the luminous intensity of an incandescent body. If in the above case, we were to compare the image of the luminous surface produced by a lens, then, evidently, two square feet of surface would simply produce a larger image than 1 square foot, but the brightness would be the same in either case.

Consequently a lens is generally used to produce an image of the radiating body whose temperature is sought. The size of an image formed by a lens does not, of course, depend upon the diameter of the lens, but only upon its focal length, but the size of the lens does effect the brightness of the image. When we stop down a camera lens, we do not change the size of the picture, but we do certainly alter the amount of light that falls upon the plate.

Furthermore, the brightness of the image of an incandescent object is not altered for different positions of the lens from the object, so long as the lens always subtends the same solid angle to any point on the image.

To be sure, as the lens recedes from the object the brightness of the image decreases as the square of the distance, but the size of the image also decreases in the same ratio, so that the illumination is concentrated, as it were, into a smaller space. The brightness, therefore, remains constant.

The eye cannot determine how much brighter one image is than another, but when two images are brought close together it can determine with accuracy when they have the same brightness.

There are four essential things to be considered in the manufacture of an optical pyrometer, namely:

1. A sensitive photometric screen.
2. A method for varying the intensity of the incident radiation.
3. An appliance for producing monochromatic light.
4. An invariable standard lamp.

Now since a thorough knowledge of the optical pyrometer must involve some notion of these details and furthermore since an improvement upon any of the pyrometers now in use

must be an improvement upon some of these essential parts, they will be taken up to some length.

1. There are a large number of photometric screens now in use, varying in sensitiveness over a wide range. In order that a photometric screen be sensitive, the two photometric fields, to be compared, must be uniform in brightness and must be separated only by a very fine line.

All the screens devised today are the results of attempts to meet these two requirements. In order to avoid any asymmetry one field is sometimes surrounded by the other, as in Fig. 3.

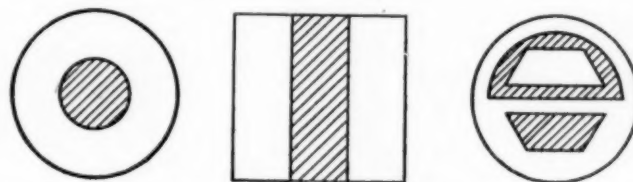


FIG. 3.—PHOTOMETRIC SCREENS.

The most familiar screens are: the Richie, a plaster paris wedge; the Jolly, two paraffine blocks separated by tinfoil; the Bunsen, a translucent greas spot on white paper, etc.

There are also other photometric devices which make use of images reflected from mirrors or shadows cast by obstacles.

Two of the most sensitive photometric screens, which by the way have never as yet been applied to any pyrometer, are the Lummer-Brodhun cube and the Brace prism. The simplest form of the Lummer-Brodhun cube is shown in Fig. 4.

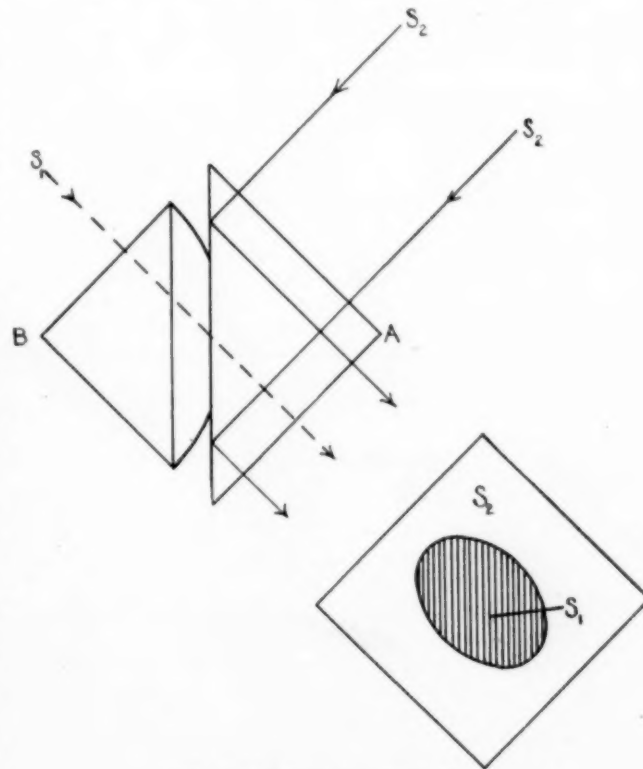


FIG. 4.—LUMMER-BRODHUN CUBE.

A is a right-angled prism with a plane hypotenuse surface, but the hypotenuse surface of B is convex, with the vertex ground flat. Light from S_1 passes through the central portion just as it would through a solid cube, so that the plane ground surface is illuminated by S_1 . Light from S_2 will be transmitted through the central portion and totally internally reflected from the region surrounding the plane ground surface so that the appearance is similar to that shown. Since the prism B can be accurately ground and closely pressed to A the dividing line between the two photometric fields is extremely small.

The Brace prism is made up of two similar 30-deg. prisms cemented together as shown in Fig. 5.

A strip ef , is silvered on one face cd , of one of the prisms. Light from the two sources S_1 and S_2 enters the prism as shown and an observer on looking in the direction co , will see the

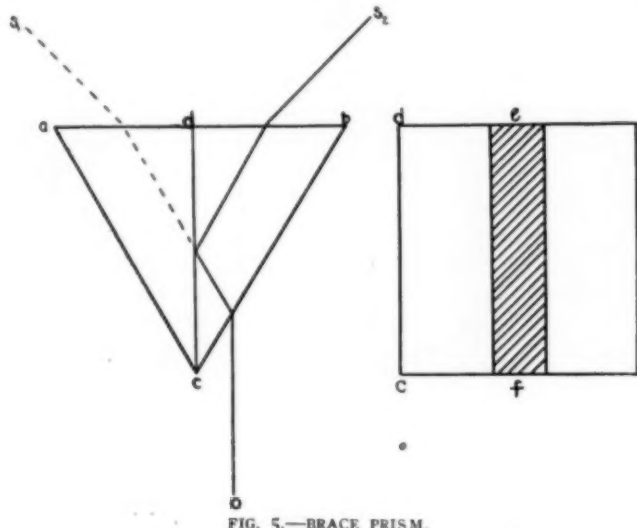


FIG. 5.—BRACE PRISM.

face, dc , illuminated by monochromatic light. The color of the face depends on the inclination of the rays. The upper third and lower third of the face are illuminated by transmitted light from S_1 while the central third is illuminated by reflected light from S_2 .

2. In order to obtain a photometric balance, it is necessary to vary the brightness of one or both of the images in a continuous manner. The method should also be determinate, i.e., it should be such that the variation can be expressed mathematically, so that it can be used in the pyrometer equation,

$$t = \frac{K_2}{K_1 - \log J} - 273 \quad (2).$$

Since in most pyrometers the intensity of the standard lamp is constant, it will be taken as unity in the following equations. In the case of an ordinary photometer, with two light sources fixed at either end of a graduated bar, equality of brightness is obtained by moving the photometric screen between the two lights.

The intensity of the unknown light in terms of the standard light taken as unity, then becomes

$$J = \left(\frac{d_s}{d_x} \right)^2$$

where

d_s = distance from screen to standard lamp, and

d_x = distance from screen to unknown source.

An adjustable diaphragm, with a square opening, placed close to the lens which forms the image, is a convenient arrangement for a portable pyrometer. Here

$$J = \left(\frac{l}{s} \right)^2$$

where

s = length of one side of the square opening.

A narrower wedge of smoked glass may also be used with advantage since it admits of easy calibration. In this case

$$\log J = C_1 x$$

where

C_1 = constant and

x = thickness of the wedge

$$\text{or } \log J = C_2 l$$

where

l = distance the wedge is moved in the direction of its length.

Lower temperatures can, however, be measured with the diaphragm.

If in order to obtain monochromatic light some form of a spectroscopic device is adopted, then the incident energy may be varied by varying the width of the collimator slit. This is generally accomplished by means of a screw with a divided head, in which case,

$$J = \frac{1}{w}$$

where

w = width of slit,

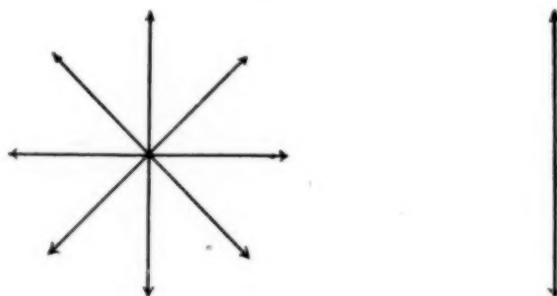
or

$$J = \frac{1}{n}$$

where

n = reading of the divided head.

A polarizing device is also convenient for portable instruments, but it absorbs considerable light and is rather difficult



Ordinary Light

Plane Polarized Light

FIG. 6.—ORDINARY AND PLANE POLARIZED LIGHT.

to construct. Now we know that light vibrations are perpendicular to the direction of propagation of the light and if by any means these vibrations, which are in all possible directions in this perpendicular plane, are reduced to one direction, the light is said to be plain polarized, Fig. 6.

If the two beams of light under consideration are plane polarized, they may be brought to equality by means of a Nicol's prism, which transmits only plane polarized light. If s_1 and s_2 represent amplitudes of vibration of two light sources and Φ the angle of rotation of the Nicol, necessary to bring the two fields to the same brightness, from Fig. 7.

$$\frac{s_1}{s_2} = \tan \Phi.$$

But since the intensity is proportional to the square of the amplitude,

$$\frac{J_s}{J_x} = \frac{s_1^2}{s_2^2} = \tan^2 \Phi \text{ or } J = \tan^2 \Phi.$$

3. Monochromatic light—red being generally used—can be produced by means of red glass and except in refined work, this is quite satisfactory. Ordinary red glass, however, cannot be used since it really transmits more than one color. Glass which is nearly monochromatic can be obtained, however, but it is sometimes necessary to use a combination of two or three pieces.

The mean wave length of the glass can be found by placing it before the slit of a spectrometer which has been calibrated in terms of wave length. To obtain light that is strictly monochromatic, a slit and a dispersion prism are generally used. The prism spreads the light out, as it were, into various colors and any particular color can be utilized by screening off the others.

4. As for a standard lamp, there is not much choice. Any oil or gasoline lamp in a place subject to drafts is likely to give trouble. Such a lamp does not require constant standardizing, however, if the tip of the flame is always brought to the same fiducial mark and if oil from the same source is always used.

A small round wick burner is not very satisfactory, since the flame, in any slight draft, is constantly getting out of the field of view.

If a small portion of a rather large flat flame were utilized, it might prove very satisfactory. Such a lamp could undoubtedly be so designed that it would not be affected by drafts.

While an electric incandescent lamp is free from these difficulties it must be constantly compared with some standard lamp. The best method of keeping a check on an electric lamp is by means of an ammeter and rheostat. It is not unreasonable to suppose that with a suitable compensating device a constant intensity electric lamp could be made, so that slight changes in voltage would not affect the intensity materially. It could then be run on any commercial 110-volt line.

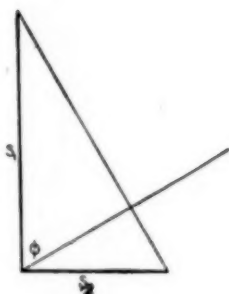


FIG. 7.—AMPLITUDE DIAGRAM.

Wauner Pyrometer.—It has been shown that the luminous intensities of two bodies may be taken as a measure of their temperatures, if monochromatic light is used, and since luminous intensities may be compared by the rotation of a Nicol prism, we have a convenient means of measuring high temperatures.

In this method comparison is made between a standard lamp and the body whose temperature is

sought. The standard used is a 6-volt incandescent lamp which is in turn compared with some primary standard as an amyl acetate lamp.

For this work the primary standard is used merely as a check for the more convenient electric lamp and so long as it is reproducible so that the comparison lamp can always be brought to the same condition, we are not concerned with its intrinsic intensity or temperature.

Photometric comparison is made of the standard lamp and the unknown source by adjusting to equal brightness two halves of a photometric field by means of a polarizing arrangement, monochromatic red light being produced by a direct vision prism.

The intensity of the unknown source in terms of the comparison lamp, taken as unity, is

$$J = \tan^2 \Phi$$

where Φ is the rotation of the Nicol prism.

Le Chatelier Pyrometer.—Le Chatelier's optical pyrometer compares the luminous intensity of the red radiation from the body whose temperature is derived with the red radiation from a standard light source.

The radiation from the body whose temperature is to be measured traverses the diaphragm D , Fig. 8, and the objective O . A part of the radiation grazes the right edge of the mirror M and is brought to a focus at the focal plane of the eye piece A . Light from the central portion of the flame of the comparison flame L traverses the objective O , is reflected from the inclined mirror M and is also brought to a focus in the focal plane of the eye piece.

Thus two images, one of the source whose temperature is sought and one of the comparison flame, are found side by side, in the focal plane of the eye piece. These two images are simultaneously observed by means of the eye piece A provided with a piece of red glass for rendering the radiations that enter the eye, the same wave length.

By adjusting the size of the aperture in the diaphragm D

these two images can be brought to the same brightness. The distance from the objective O to the focal plane of the eye piece can be varied in order to focalize the radiation from the luminous source and the distance can be read directly from a scale engraved on the draw tube. The aperture in the dia-

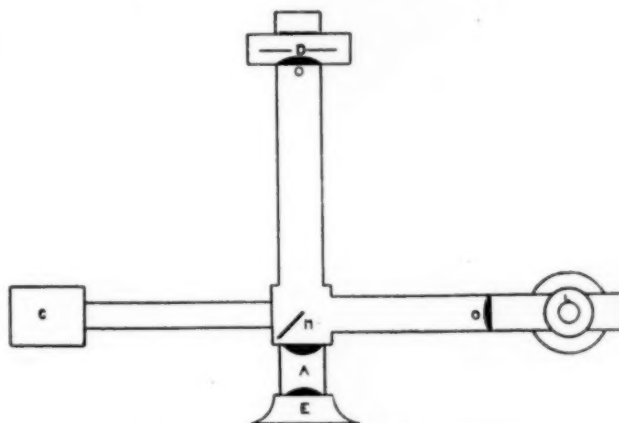


FIG. 8.—LE CHATELIER OPTICAL PYROMETER.

phragm D is square and the length of one side can be read directly from the screw head which operates it.

The intensity of the unknown source in terms of the intensity of the comparison lamp taken as unity, becomes

$$J = \left(\frac{1}{s} \right)^2$$

where s denotes the length of one side of the square aperture D . Due to the lack of monochromatism of the red glass this instrument is not so accurate as the Wauner.

Holborn-Kurlbaum Pyrometer.—In this method the luminous intensity of the comparison source is varied until a photometric balance is obtained between its image and the image of the incandescent object in question.

In the H.-K. (Holborn-Kurlbaum) pyrometer shown in Fig. 9 a small electric lamp L is placed in the focal plane of the objective O , and the same is viewed by means of an eye lens E .

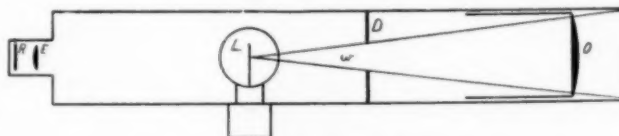


FIG. 9.—HOLBORN-KURLBAUM PYROMETER.

In making an observation the pyrometer is focused upon the object whose temperature is sought, thus bringing the image of the object in the plane of L .

The current through the lamp is adjusted by means of a rheostat until the lamp filament disappears against the bright background. The value of the current strength can be read direct from a milli-ammeter.

In order to measure temperature with this instrument, it must be empirically calibrated by means of a black body. A curve may then be plotted with current in milli-amperes and temperature in degrees C.

To determine an unknown temperature, it is only necessary to focus the instrument upon the object in question and adjust the current through the lamp until the filament disappears against the bright object. The pyrometer then indicates black-body temperature unless black-body conditions are realized, in which case it indicates true temperature, i.e., thermodynamic temperature.

The reading of the ammeter will be independent of the distance of pyrometer from object so long as the solid angle w in Fig. 9 is constant. This is accomplished by means of the diaphragm D . When the instrument is focused for distant ob-

jects, i.e., when O is drawn near L , the solid angle w would be increased if it were not for the diaphragm D .

The light which reaches the eye is rendered approximately monochromatic by a red glass, R , placed before the eye piece, but for temperature below 800 deg. C. this is not necessary and above 1200 deg. C. two glasses are generally used.

The H.-K. pyrometer is probably the most sensitive pyrometer now in use.

Morse Thermo-Gage.—This is somewhat similar to the Holborn-Kurlbaum pyrometer, in that it utilizes the disappearing-filament principle, but it is not nearly so precise, since it is not provided with any lens system or monochromatic glasses. It is simply an incandescent electric lamp in a black tube and it is operated and calibrated in a similar manner to the Holborn instrument.

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Calculation of Furnace Charges.—V.

By REGIS CHAUVENET.

The preceding "type" problems were one and all presented under the suppositions: (1) That matte has already been "taken out," (2) that the "conversion" factors have been applied, reducing all bases to the two standards, viz., FeO and CaO, (3) that the figures denoting percentages in the analyses have been simplified by addition and subtraction, so as to present integers only for use in computation.

The student must observe that in all of this *preparation* there is no difference between the excess and the equation methods. The same is true of the "proof," which can be done perfectly in one way only, viz., by taking the ascertained weights of the materials and having calculated from their analyses the respective total of each constituent, add like to like, and make the numerical comparison, when, if the computation is entirely correct, the proportions will exactly conform in ratio to the "requirements" on which the problem was "set up."

But as to the operation proper, the equation method claims directness, and obviates all necessity of trial and readjustment. It is, furthermore, better suited to complex cases. Looking over the five cases given in Article IV it is seen that there is very little more work in the solution of the last case than of the first. Yet the complexity rises from the first to the last of these cases, as to number of constituents involved.

In those problems in which there is but a single adjudication, between one "acid" and one "base" the equation method claims no special advantage. But in a very great majority of copper and lead smelting problems there will be more than two "elements" to be charged, and more than one base to be considered. We follow here the usual rule, which is to class all bases under one group or the other, viz., iron-oxide or lime.

In regard to alumina we have already shown the common iron practice, that is, to regard it as "acid" and add its percentage to that of silica.

Another practice has been briefly mentioned, i. e., to neglect the element entirely, in calculation, trusting the fluidity of the slag to "take care" of it. The practice might, however, if pushed too far, play a disagreeable trick on the practitioner some day.

Two facts, neither of them very clearly proved, but probably to be classed as reasonable "working theories," may be stated about the action of alumina in the smelting furnace.

(1) In a very basic mixture it probably takes up the "acid" rôle, and in so far an element of safety, i. e., by preventing what might otherwise be a dangerous condition, the stiffening of the slag owing to excessive basic contents.

(2) It is safer to figure on alumina in an acid rôle at the

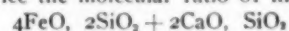
high temperatures of the iron furnace than at the lower range of lead and copper smelting.

In the calculations hitherto illustrated, little attention has been paid to formulas, and in the five "type" cases setting forth the method of equations the requirements were confined strictly to "percentage" slags.

The reason why it is not necessary to make much account of formulas has been partly explained. It is, in a word, because any formula may be transformed into the analytical form in a few minutes' work.

There are cases, nevertheless, in which it may be easier not to translate into the complete analytical form, but to make our statement dependent directly upon the chemical ratio. Some illustrations follow. The reader will, of course, have noticed that in the examples we have made the slag requirements in round numbers. This was chiefly for the sake of simplicity in a first presentation, but we will now point out that in the consideration of formulas we may often secure ratios that will serve as factors much simpler than the requirements derived from "translating" from formula into full analysis.

Example.—Let the type chosen be a singulo silicate, with iron oxide in twice the molecular ratio of lime.



The molecular weights are $3\text{SiO}_2 = 180$; $4\text{FeO} = 288$ and $2\text{CaO} = 112$.

No very great arithmetical "perception" is needed to see that these numbers approximate the ratio 3:5:2. It is true that this also comes out plainly in the analytical form, viz.:

| | |
|------------------------|----------------|
| SiO ₂ | 31.03 per cent |
| FeO..... | 49.65 " " |
| CaO..... | 19.31 " " |

but anyone used to looking at numbers with their ratios in mind would see the ratio without having to take the trouble of converting the formula into the analysis. There are cases in which the "chemical" numbers are manifestly in simple ratio, when the analysis does not so quickly reveal the latter.

Let us now set up a problem on the above "formula."

We shall now assume materials not quite so simple in analytical percentage figures as in the "type" cases.

| | Ore. | Iron flux. | "Stone." |
|------------------------|---------|------------|----------|
| SiO ₂ | 39..... | 8x..... | 7y |
| FeO..... | 14..... | 76x..... | |
| "Base"..... | 6..... | 7x..... | 52y |

It is in this way that the analyses may always be set down in using the "equation" method. As we are going to let 100 x equal the pounds of iron flux and 100 y equal the pounds of limestone, we write the letters x and y directly into the analyses for reference afterward.

Here, as elsewhere, we set down trivial details. This one might raise a smile because of its trifling nature. We smile also. But we do not cancel the detail. We know that every little scrap of precaution against error is of value. One of these is to always use the same order of procedure, another is to use the same abbreviations, an important one is to "label" your side calculations, for though at the moment of making them you know well enough what they mean, you may have a good deal of trouble in finding them later if they are lost amid a maze of "scribble" figures.

Requirement.—As we found above that the ratio of 3:5:2 for silica, iron-oxide and lime respectively satisfied our formula pretty closely, we adopt it. Now we write:

$$\text{SiO}_2 : \text{FeO} = 3 : 5 = 39 + 8x + 7y : 14 + 76x$$

$$\text{FeO} : \text{base} = 5 : 2 = 14 + 76x : 6 + 7x + 52y$$

Nothing remains but the mechanical work of reducing these proportions to equations and solving them. It is this extreme simplicity of statement as substituting the "excess" calculations, that constitutes the advantage of the method under discussion. The values of x and y are as below:

$$x = 0.8866 \cdot 100x = 88.66 \cdot y = 0.3913 \cdot 100y = 39.13$$

That is, take 88.66 lb. of the "iron flux" and 39.13 lb. of the "stone."

Proof.

| | SiO ₂ | FeO. | Base. |
|----------------------|------------------|------------|-----------|
| From the ore..... | 39.00..... | 14.00..... | 6.00 lb. |
| From the "flux".... | 7.09..... | 67.38..... | 6.21 " |
| From the "stone".... | 2.74..... | ..... | 20.35 " |
| | 48.83 | 81.38 | 32.56 lb. |

These three summations, representing the respective weights of the constituents, are exactly in the triple ratio of 3:5:2, as required

There are many who object to the use of equations in any computation, and we have even seen in a well-known metallurgical work a chapter devoted to "slag calculation" in a highly unsystematic form, followed by a self-congratulatory remark that there was no "x" or "y" in the method.

To such, however, as are not terrified by the first elements of algebraic statement we will propose the testing of this "slag method" by the time needed to complete the work. The last problem cannot be called very complex. Try it by excess and adjudication, then by equations, as here illustrated. The method can certainly not be charged with indirectness. No one who has once used a process which goes straight to a precise answer will afterward be content to use approximations and re-adjustments.

The operator can choose for himself in any case whether to calculate upon original analyses or to accept a reasonable approximation.

In iron metallurgy formulistic requirements are no longer much regarded. The astonishing variations which can be tolerated in the ratio between the "acid" (SiO₂ + Al₂O₃) and the "base" indicate that the question of formula assumes less importance at these high temperatures. In short, fluidity of a slag being only partly a matter of composition and partly a matter of temperature, considerations other than those of the oxygen ratio come into play.

Slags from the lead furnace (and probably from other operations) which show a distinctly crystalline structure will, it is claimed, always be found to have a chemical formula as the expression of their compositions.

Certain formulistic "types" with analyses and ratios either exact or approximate are annexed. They could be varied almost indefinitely. They are not introduced as primarily "working types," but merely to show how in many cases fairly simple ratios may be substituted for percentages of analytical statement. Much has to be left to individual device in the simplification of data.

The "ratios" which are placed to the right of each analysis do not in any case greatly differ from the relative proportions of the latter, and in some cases they are practically identical. Introduced as factors in a statement by proportion they would in most instances simplify the "setting up" of the problem.

The slags presented are all of the "two base" type, assumed as usual as iron oxide and lime.

Simplified analyses are also annexed, i.e., original analyses slightly revised by elision of fractional parts.

Some Well-Known "Formulas."

(1) Singulo with iron oxide and lime in equal chemical ratio.

| | (FeO) ₂ , SiO ₂ + (CaO) ₂ , SiO ₂ | |
|------------------------|---|---------|
| | Per cent. | Ratios. |
| SiO ₂ | 31.91 | 15 |
| FeO | 38.30 | 18 |
| CaO | 29.79 | 14 |

(2) Sesqui-silicate, same ratio as between iron and lime.

| | 4FeO, 3SiO ₂ + 4CaO, 3SiO ₂ | |
|------------------------|---|---------|
| | Per cent. | Ratios. |
| SiO ₂ | 41.28 | 5 |
| FeO | 33.03 | 4 |
| CaO | 25.69 | 3 |

(3) Bi-silicate, iron oxide and lime in equal ratio.

| | FeO, SiO ₂ + CaO, SiO ₂ | |
|------------------------|---|---------|
| | Per cent. | Ratios. |
| SiO ₂ | 48.39 | 15 |
| FeO | 29.03 | 9 |
| CaO | 22.58 | 7 |

(4) Singulo, iron oxide twice chemical ratio of lime.

| | 4FeO, 2SiO ₂ + 2CaO, SiO ₂ | |
|------------------------|--|---------|
| | Per cent. | Ratios. |
| SiO ₂ | 31.03 | 3 |
| FeO | 49.65 | 5 |
| CaO | 19.31 | 2 |

(5) Sesqui-silicate, iron oxide twice lime.

| | 8FeO, 6SiO ₂ + 4CaO, 3SiO ₂ | |
|------------------------|---|---------|
| | Per cent. | Ratios. |
| SiO ₂ | 40.31 | 15 |
| FeO | 42.98 | 16 |
| CaO | 16.71 | 6 |

(6) Bisilicate, iron oxide twice lime.

| | 2(FeO, SiO ₂) + CaO, SiO ₂ | |
|------------------------|---|---------|
| | Per cent. | Ratios. |
| SiO ₂ | 47.37 | 6 |
| FeO | 37.90 | 5 |
| CaO | 14.73 | 2 |

We now return to an actual computation, taking for the purpose the iron furnace problem already given in article III, both analyses and requirements as to composition of the slag being identical. We repeat the data however.

Analyses of the iron ore, coke and limestone.

| | Ore. | Coke. | Limestone. |
|--------------------------------------|----------|----------|------------|
| SiO ₂ | 4 | 4 | 5 per cent |
| Al ₂ O ₃ | 2 | 1 | 2 " " |
| MgO | 4 ..... | .. .. | 2 " " |
| CaO ..... | .. .. | .. .. | 50 " " |
| Fe ₂ O ₃ | 90 ..... | .. .. | " " |
| Carbon ..... | .. .. | 95 | " " |

Requirement for the slag is that the "acid" considered as silica plus alumina shall be to the total "bases" (CaO + MgO) as 10 : 12.

Find limestone required for 100 lb. of ore, also for 100 lb. of coke.

This was done by the "excess" method in article III, we now do it by the equation method.

(1) Ore 100 lbs. Limestone = 100 x lb.

"Acid" = 6 + 7 x lb. Base = 4 + 52 x lb.

12(6 + 7 x) = 10(4 + 52 x) or, in equation form:

72 + 84 x = 40 + 520 x.

Whence

x = .0734 and 100 x = 7.34 = lb. limestone required.

(2) Coke. Since "acid" in the coke is 4 + 1 or 5 x we have

12(5 + 7 x) = 10(52 x).

x = .1376 and 100 x = 13.76 = lb. limestone required.

That is, we take for each 100 lb. ore, 7.34 lb. limestone, and for each 100 lb. coke, 13.76 lb. limestone.

These results are identical with those previously found by the excess method. Proof by "checking out" was given in full in article III, so it would be superfluous to repeat it here.

This is an exceedingly simple case. We have already mentioned that the advantage of the equation method comes out in complex problems, but even here comparison will show that the computation is less by many figures than by getting the "excess."

We have said that "formulas" are not much used in iron smelting. However, we now give one problem with a formulistic requirement.

This also has been given in article III. In it, we shall regard alumina as a base, and instead of making a separate computation for coke, we assume the latter as constant, and as 70 per cent of the weight of the ore.

Analyses of material.

| | Ore. | Limestone. | Coke. |
|--------------------------------------|------|------------|------------|
| SiO ₂ | 8 | 6 | 8 per cent |
| Al ₂ O ₃ | 5 | .. | " " |
| MgO | .. | 6 | " " |
| CaO | .. | 46 | " " |
| Fe ₂ O ₃ | 87 | .. | " " |

Take 100 lb. ore as usual as basis for calculation.

Reduce alumina and magnesia by "factors" to the lime basis, instead of "lumping" them by mere addition. After presenting the "revised" analyses, figure for a "singulo" silicate on the lime basis alone.

Take out 3 per cent silica from the ore, for silicon in the pig metal.

Factors are 1.4 for MgO and 1.65 for Al₂O₃.

CaO equivalent for Al₂O₃ in the ore = $1.65 \times 5 = 8.25$.

CaO equivalent for MgO in the stone = $1.4 \times 6 = 8.4$.

Revised analyses (iron omitted, 3 per cent off of the silica).

| | Ore. | Stone. | Coke. |
|------------------------|------|--------|------------|
| SiO ₂ | 5 | 6 | 8 per cent |
| "CaO" | 8.25 | 54.4 | " " |

70 lb. coke will give $8 \times .70$ lb. SiO₂ which added to the 5 lb. in the ore will give us $5 + 5.6 = 10.6$ lb. SiO₂ to be reckoned in the slag from ore and coke.

Call the limestone 100 *x*.

SiO₂ = $10.6 + 6x$. CaO = $8.25 + 54.4x$.

Calculation of the ratio in the lime singulo formula shows that it will contain 35 per cent silica and 65 per cent lime, that is:

$$10.6 + 6x : 8.25 + 54.4x = 35 : 65.$$

$100x = 26.44$ lb. = limestone to be added.

Compare with result in article III. The discrepancy, which is less than half a pound, is merely apparent, being due to dropped decimals in the "excess" computation.

Computation of a Copper Matte and Slag Case by Equations.

Again comparing length of the operation, we find that the equation is far ahead in preparation and statement. The use of the "factors" is the same in both. Ten minutes suffices for preparation, solution and proof.

We shall mix two ores and use an "iron flux," limestone and coke.

Analyses of material.

| | Ore I. | Ore II. | Iron flux. | Stone. | Coke. |
|--------------------------------------|--------|---------|------------|--------|-------|
| SiO ₂ | 45 | 42 | 5 | 4 | 8 |
| Al ₂ O ₃ | 6 | 3 | 2 | 2 | 4 |
| Fe | 20 | 23 | 63 | .. | .. |
| Cu | 12 | 6 | .. | .. | .. |
| CaO | 3 | 6 | 2.3 | 46 | .. |
| MgO | 1 | 4 | .5 | 6 | .. |
| S | 6 | 9 | .. | .. | .. |
| As | 1 | .. | .. | .. | .. |
| C | .. | .. | .. | .. | 88 |
| Deficit | 6 | 7 | 27.2 | 42 | .. |
| | 100 | 100 | 100 | 100 | 100 |

The 63 Fe in iron ore = 81 of FeO.

Coke to be assumed as 12 per cent of the weight of the ore charged.

The two ores are to be mixed so as to obtain eight (8) per cent of copper in the mixture.

100 lb. of the "mix" is the basis of calculation, as usual.

Assume no loss of sulphur or arsenic in the smelting.

"Convert" all the bases except iron oxide to the lime basis, calculating slag as of two bases, viz: FeO and CaO.

In presenting analysis of the "mix" add in the silica and alumina from the 12 per cent of coke, so as to bring the coke into the general computation without having to treat it separately.

Assume the usual ratios for copper and iron with sulphur, viz: Cu₂S and FeS, and put all the arsenic into speiss assumed as Fe₃As.

Requirement for the slag is that:

$$\text{SiO}_2 : \text{FeO} : \text{CaO} = 4 : 5 : 2.$$

(1) Coke is 12 per cent of the ore. As its silica is 8 per cent of its own weight, we have $8 \times .12$, say 1 lb. silica added for each 100 lb. ore. and $4 \times .12$, say 0.5 lb. alumina added for each 100 lb. ore. It will be convenient to incorporate these little additions into the analysis of the "mix" and have done with the slight complication of the coke ash. That is, from that point we calculate exactly as though these little quantities had formed part of the ore constituents.

(2) Mix the two ores. The rule is easily applied, as follows:

The copper percentage of the richer ore is 12, the percentage of the required mix is 8; then, $12 - 8 = 4$.

Also the required percentage minus the lesser percentage is $8 - 6 = 2$.

Take the weights of the two ores then, inversely as these figures, i.e., 2 parts of ore I to 4 parts of ore II., which of course reduce to 1:2 parts.

Add each percentage figure in analysis No. I to twice percentage figure of same element in analysis No. II and divide each sum by three.

Analysis of the mixed lot adding in the coke ash as directed will be:

| | | |
|--------------------------------------|-----|----------|
| SiO ₂ | 44 | per cent |
| Al ₂ O ₃ | 4.5 | " " |
| Fe | 22 | " " |
| Cu | 8 | " " |
| CaO | 5 | " " |
| MgO | 3 | " " |
| S | 8 | " " |
| As | .33 | " " |

(3) Take out matte and speiss.

(a) Copper. $4 : 1 = 8 : 2 = \text{Cu}_2 : \text{S}$.

Weight of copper, 8 lb.; of sulphur 2 lb.; of Cu₂S = 10 lb.

(b) Arsenic with iron, $75 : 5 \times 56 = 15$; $56 = .33 : 1.23 = \text{Fe with As}$. Weight of the "speiss," $1.23 + .33 = 1.56$ lb.

(c) Residual sulphur with iron.

Original sulphur was 8 lb., taken out for copper 2 lb., remains 6 lb.

$32 : 56 = 4 : 7 = 6 : 10.5 = \text{iron to combine into matte}$. Weight of sulphur = 6 lb.; of iron 10.5 lb.; weight of iron matte 16.5.

(d) Residual iron to be computed into the slag.

Original iron 22 lb., taken out by arsenic 1.23 lb., by sulphur 10.5 lb., total 11.73 lb. $22 - 11.73 = 10.27$ lb. residual iron.

Fe : FeO = $56 : 72 = 10.27 : 13.2 = \text{lb. FeO to be used for slag}$.

This completes "taking out the matte." The slag problem is "cleared" of sulphur, arsenic, copper, and of all the iron except the 13.2 FeO which must be figured with the group of "iron" (in this case all really iron) in the final adjudication.

The next procedure is to "convert" alumina and magnesia into "lime."

(4) "Conversions."

(a) Ore.

Al₂O₃; $4.5 \times 1.65 = 7.4 = \text{CaO from alumina}$.

MgO; $3 \times 1.4 = 4.2 = \text{CaO from magnesia}$.

CaO; $5 \times 1 = 5.0 = \text{CaO actual lime}$.

Total.....16.6 = CaO for computing.

(b) Flux.

$\text{Al}_2\text{O}_3; 2 \times 1.65 = 3.3 = \text{CaO from alumina.}$
 $\text{MgO}; .5 \times 1.4 = .7 = \text{CaO from magnesia.}$
 $\text{CaO}; 2.3 \times 1 = 2.3 = \text{CaO actual lime.}$

Total..... 6.3 = CaO for computing.

(c) Stone.

$\text{Al}_2\text{O}_3; 2 \times 1.65 = 3.3 = \text{CaO from alumina.}$
 $\text{MgO}; 6 \times 1.4 = 8.4 = \text{CaO from magnesia.}$
 $\text{CaO}; 46 \times 1 = 46.0 = \text{CaO actual lime.}$

Total..... 57.7 = CaO for computing.

We have in this case assumed the Stoichiometric conversions, instead of merely adding the weights arbitrarily to the lime figures. It is certainly a more rational proceeding.

It may be neglected when the alumina or magnesia is in very small percentage.

We are now ready to present the completely "prepared" analyses, using the usual convention of 100 x for the "flux" and 100 y for the limestone.

Revised analyses ready for computation.

| | Mix + ash. | Iron flux. | Stone. |
|----------------------|------------|------------|----------|
| SiO_2 | 44 | 5 x | 4 y |
| FeO | 13.2 | 81 x | .. |
| CaO | 16.6 | 6.3 x | 57.7 y |

Formulistically the requirement is too far from the singulo:
 $2(\text{FeO})_2\text{SiO}_2 + (\text{CaO})_2\text{SiO}_2$, analysis of which would be as follows:

| | |
|----------------------|----|
| SiO_2 | 31 |
| FeO | 50 |
| CaO | 19 |

It is fairly close to the sesqui-silicate;

$2(\text{FeO})_2(\text{SiO}_2)_3 + (\text{CaO})_2(\text{SiO}_2)_3$, whose analysis is:

| | |
|----------------------|------|
| SiO_2 | 40.3 |
| FeO | 43.0 |
| CaO | 16.7 |

For the ratio $\text{SiO}_2 : \text{FeO} : \text{CaO} = 4 : 5 : 2$, on which we are to compute, gives the exact analysis:

| | |
|----------------------|----------------|
| SiO_2 | 36.36 per cent |
| FeO | 45.45 " " |
| CaO | 18.18 " " |
| | 99.99 " " |

The equations are at once set up as follows:

$(\text{SiO}_2 : \text{FeO} = 4 : 5) \quad 5(44 + 5x + 4y) = 4(13.2 + 81x)$
 $(\text{SiO}_2 = 2\text{CaO}) \quad 44 + 5x + 4y = 33.2 + 12.6x + 115.4y$
 $x = 0.5631 \quad 100x = 56.31. \quad y = 0.05853 \quad 100y = 5.853.$

That is, we take 56.31 lb. of the "flux" and 5.853 lb. of the limestone.

Proof. (Assemble expressions for constituents and find values in pounds by substitution.)

| | SiO_2 | FeO | CaO |
|----------------|----------------|--------------|--------------|
| Ore, etc. | 44.0 | 13.20 | 16.6 |
| Flux | 2.816 | 45.61 | 3.55 |
| Stone | .234 | .. | 3.38 |
| | 47.05 | 58.81 | 23.52 |

Compare these weights and we find that:

$47.05 : 58.81 : 23.52 = 4 : 5 : 2$ exactly.

If, in using the values of x and y in the "proof" we find that two of the constituents come out in exact ratio, but the third is more or less "off," there is an error in all three of the quantities, and the equation must be solved again. This is sometimes a puzzle to the inexperienced computer, who imagines in such a case that the two quantities which come out "straight" must be correct, and that the only error is in the third. This is not true. The proof must bring out the triple ratio perfectly; then it is certain that all the "elements" are correctly determined.

Here we may again remind the operator that if he has been

computing for a slag which is impossible under the conditions imposed by the materials, he will get a "minus" value for one of his unknown quantities. In the above case, a very slight increase in the "bases" in the ore, with corresponding decrease of silica, would bring y to a minus value; in other words, there would be more than enough "base" in the other constituents, and the use of the limestone would be uncalled for.

Now, to re-state conditions and outcome of the problem, and get composition of the products, we charge:

| | | |
|-----------------|-------|-----|
| Ore mix | 100 | lb. |
| Coke | 12 | " |
| Iron flux | 56.31 | " |
| Limestone | 5.85 | " |

Products: Slag, 129.39 lb., composition by ratios as per requirements, analysis as stated above.

Matte and speiss, 28.06 lb.

Composition:

| | | |
|---------------|-------|----------|
| Copper | 28.51 | per cent |
| Iron | 41.80 | " " |
| Sulphur | 28.51 | " " |
| Arsenic | 1.17 | " " |
| | 99.99 | " " |

Considerable time may be saved in the solution of equations similar to the above by dropping fractional parts. To this there are certain objections. The most important is this, viz.: just as in bookkeeping, a slight difference in the "balance" may indicate a much larger one in fact, so in a check on operations like the above (since if you omit small fractions you are certain not to obtain a perfect proof), you are left in an uncertainty as to whether the failure to "balance" is due to the dropping of decimals, or to some actual error in computation.

The proper place for "short cuts" in any operation must be left to the judgment of the operator. The best check after all is the execution of the problem in all its rigor, because you then have the satisfaction of a perfect proof. *It is all right to drop decimals of pounds from the results.*

We close this series with a few problems, which are left without operations, though the answers are given. They are all of the same general nature as those hitherto presented, and all may be easily solved by the method of "Representative equations."

(a) Three ores, supposed to be each obtainable in suitable quantities, are to be mixed for smelting without addition of any other material, i.e., they are to constitute a "self-fluxing" mixture. Analyses, so far as regards slagging elements, are as follows:

| | I. | II. | III. |
|-----------------------------------|----|-----|------|
| Silica | 50 | 10 | 20 |
| Iron oxide (FeO) | 20 | 70 | 10 |
| All other bases | 10 | 5 | 40 |

Assume 100 lb. of No. I as basis for the mixture. The slag produced is to have this composition, viz.: Silica, 40; Iron oxide, 30, and all other bases, 30 per cent. Find weights of the other two ores.

Answer.

| | | |
|---------------|-------|-----|
| No. I | 100 | lb. |
| No. II | 37.1 | " |
| No. III | 113.7 | " |

Weight of ore charge..... 250.8 "

Proof.

| | SiO_2 | FeO | Bases. |
|-------------|----------------|--------------|--------|
| I | 50.00 | 20.00 | 10.00 |
| II | 3.70 | 25.97 | 1.85 |
| III | 22.74 | 11.37 | 45.48 |
| Totals..... | 76.44 | 57.34 | 57.33 |

$76.44 : 57.34 : 57.33 = 40 : 30 : 30.$

(b) We have a calcined ore, to be smelted for matte with-

out any additional fluxes. The following assumptions are made as to action in the furnace, viz.:

All the copper enters the matte. Three-fourths of the lead and one-half of the zinc also go into the matte, taking precedence of the iron. All remaining sulphur goes into the matte as FeS.

One-half of the zinc goes into the slag, and one-fourth of the lead. All iron not in matte goes into the slag.

Take 100 lb. of the ore, find weight and analyses of matte and slag. No allowances for losses.

Analysis of the ore.

| | |
|------------------------|---------------|
| SiO ₂ | 27.3 per cent |
| Cu | 11.9 " " |
| Fe | 37.5 " " |
| Zn | 2.0 " " |
| Pb | 1.0 " " |
| CaO | 4.0 " " |
| S | 7.0 " " |
| O and loss | 9.3 " " |
| Total | 100.00 " " |

Answers.

Weight of matte per 100 lb. of ore taken = 26.65 lb.

Analysis of the matte as follows:

| | |
|-------------------------|----------------|
| Cu ₂ S | 55.91 per cent |
| FeS | 35.27 " " |
| ZnS | 5.63 " " |
| PbS | 3.19 " " |
| ..... | 100.00 " " |

Weight of slag per 100 lb. of ore taken = 73.35 lb. *Analysis:*

| | |
|------------------------|----------------|
| SiO ₂ | 37.24 per cent |
| FeO | 55.23 " " |
| CaO | 5.45 " " |
| ZnO | 1.71 " " |
| PbO | 0.37 " " |
| ..... | 100.00 " " |

(c) A partly roasted ore contains:

| | |
|--------------------------------------|----------------|
| SiO ₂ | 62.00 per cent |
| Al ₂ O ₃ | 10.00 " " |
| Fe | 14.42 " " |
| Cu | 6.40 " " |
| S | 4.51 " " |

Take out matte Cu₂S + FeS, use for flux a limestone containing 10 per cent silica and 50 per cent lime. Slag is to be a bi-silicate, no special ratio being required as between bases. Find analysis of the slag.

Answer.

| | |
|--------------------------------------|----------------|
| SiO ₂ | 56.38 per cent |
| Al ₂ O ₃ | 8.07 " " |
| FeO | 9.68 " " |
| CaO | 25.87 " " |
| ..... | 100.00 " " |

(d) Copper matte smelting, no flux except limestone.

Analysis:

| | Ore. | Ash of coke. | Limestone. |
|------------------------|--------|--------------|------------|
| SiO ₂ | 30.00 | 80.00 | 7.00 |
| Bases | 13.00 | 20.00 | 52.00 |
| Fe | 28.00 | ..... | ..... |
| Cu | 6.00 | ..... | ..... |
| Zn | 6.00 | ..... | ..... |
| S | 12.00 | ..... | ..... |
| Def. | 5.00 | ..... | ..... |
| ..... | 100.00 | ..... | ..... |

Calculate for 100 lb. ore. Coke to be twelve and a half per cent of the ore. Percentage of ash in the coke = 16.

Condition for slag is simply "Silica, 40 per cent, all bases, 60 per cent."

The following assumptions are made:

All copper goes into matte as Cu₂S.

Half of the iron goes into the matte as FeS half into slag.

Half of zinc for matte, half for slag.

Excess of sulphur over these requirements is supposed to be lost.

Find. First. Weight of the matte and its composition.

Second. Weight of limestone required.

Answers.

Weight of matte to 100 lb. ore = 34 lb.

Composition as follows:

| | |
|---------------|---------------|
| Iron | 41.2 per cent |
| Copper | 17.6 " " |
| Zinc | 8.8 " " |
| Sulphur | 32.4 " " |
| ..... | 100.00 " " |

Limestone required per 100 lb. ore = 28.92 lb.

The student wishing to acquire familiarity with this method of slag computation will find the exercises and illustrations here given quite enough to render its practice both convenient and rapid.

Circular on Regulations for Illuminating Gas.

The National Bureau of Standards is about to issue a circular entitled "State and Municipal Regulations for the Quality, Distribution and Testing of Illuminating Gas." This circular (133 pages, uniform in style with other Bureau circulars) has been prepared after conference and correspondence with a large number of gas engineers and inspectors; and it represents, as nearly as possible, the average opinion of many men active in the field of gas manufacture and gas testing.

Part I of the circular gives a summary of the municipal gas ordinances now operative, presents a general discussion of municipal gas requirements, and proposes an ordinance largely compiled from the best ordinance requirements now in force.

Part III quotes a few ordinances typical of those recently enacted and gives the main portions of state gas laws now in force affecting gas quality, pressure and meter accuracy.

The circular does not concern itself with financial regulation of gas companies, nor does it include any discussion of the comparative value of various methods of works management. It deals mainly with the candlepower, heating value, purity and pressure of the gas and gas meter testing.

The present publication has grown out of the investigation of the methods and standards employed in gas photometry and gas calorimetry, undertaken by the Bureau three years ago. A second circular on the methods of testing employed for official inspection work is now being prepared. Although it cannot be expected that the regulations for or methods of gas testing will ever be entirely uniform throughout the country, it is believed that if the results of a comprehensive investigation of the subject are published a greater uniformity of method, and in some cases more accurate measurements will result.

The attitude of the Bureau of Standards is entirely advisory and its intention is to place in the hands of the technical and general public an impartial and, as nearly as may be, an accurate summary of the facts which must be considered in connection with the fixing of standards of quality and the testing of illuminating gas.

Revision of the circular from time to time is contemplated in order to amend the recommendations as to the requirements to adapt it to new developments in the gas industry.

The circular is now in press and will be ready for distribution soon after April first. Copies may be obtained free of charge by addressing The Director, Bureau of Standards, Washington, D. C.

A Shaking Inclined-Screen Hydraulic Classifier*

By LEWIS B. SKINNER.

A great deal of time and money has been spent in designing and developing various forms of classifiers. Almost without exception inventors have worked along the lines known as "direct" classification, i.e., a system in which, either with or without the addition of hydraulic water to the pulp, the coarsest particles are separated first and the slime last, with intermediate grades. This system offers the very serious objection that the finer grades become greatly diluted, especially when a hydraulic stream has been used in separating each of the coarser grades. This makes it necessary to thicken the fine grades, and introduces complications in mill design and operation. When, therefore, Dr. Richards advocated the use of "indirect" or "inverted" classification, wherein the slime could be eliminated first and the coarse grade last, with corresponding intermediate grades, he took a step in advance, and classification was simplified and improved.

Nevertheless, it has seemed to me that further improvements might be made in the Richards pulsator classifier by (1) providing means independent of the hydraulic water for transporting

urn beneath the fifth compartment. The discharge openings of the various compartments are arranged on a descending line parallel with the bottom of the classifier. Although Mr. Henderson says that this device gave excellent classification, it was still open to some criticism. The capacity was comparatively low and there was a tendency for the hydraulic water coming through one narrow slot at high velocity in each compartment, to force too much coarse pulp up into the various compartments, whence it would have to settle again with no hydraulic water or vibrating motion to agitate it before arriving at the next slot. This caused "banking up."

From the suggestion offered by this classifier, I thought that improvement might be made in the standard Richards pulsator by the use of a sloping instead of a horizontal screen. I built a machine placing the screen at an angle of $22\frac{1}{2}$ deg. and got good results, but came to the conclusion that even less pitch would be better. The inclination of the screen made possible the use of gravity for the transportation of the ore, assisted by the vibration produced by pulsations. The largest particles rolled down the screen fast, the intermediate not as fast, while the lightest remained behind. In this way all particles tended to reach their proper compartments by gravity alone and were more properly acted upon by just the hydraulic current necessary to separate them from the balance of the material.

After experimenting with this machine I found classification materially improved, screen analyses and analytical work showing the different grades to contain coarse gangue and fine mineral. Instead of using fixed overflow gates on the different compartments I used adjustable slides with a comparatively small hole in each to regulate the quantity of hydraulic water drawn from each compartment. The slides were so arranged that the head of water in any compartment was about one inch higher than in the preceding compartment, thus reversing the condition in the standard Richards machine. By this arrangement the difference in head between the water column in the last and the first compartment tended to create a gentle flow of water counter to the ore stream, instead of parallel with it as in the Richards machine, thereby preventing fine material from getting beyond the compartment in which it should have been sorted out. The counter current, of course, would take the path of least resistance which would be at the top of the bed where the finer material would be.

I argue that if one wishes to dissolve a soluble gas in water he does not parallel the gas stream and the solvent stream. He has them run counter to each other. Just so, in a classifier, the ore stream should not be parallel to the water current, but should be opposed to it. This is possible in classification only by using gravity to move the ore, with the water flowing in the opposite direction; and in this type of classifier this can be done only by screen inclination.

The wearing of screens in this design was materially reduced. In the original machine the screen was changed every two weeks or so, until a punched screen was substituted for woven wire, and even then the wear was excessive, as the screen lasted only about three weeks. In the original Richards they cracked at the edges on account of the weight of the ore carried. With the inclined screen, however, it was necessary to make but one change of screens in over a year, and this change was necessary on account of the carelessness of a workman who damaged a screen which had been in service for nine months.

Further experience with the altered classifier just described convinced me that still greater improvement was possible, provided the different forces acting in the classifier could be brought under separate means of control, and each made to do its work independently of the others. Some form of the vibratory or pulsating motion is certainly desirable, but in order to be most efficient it should act as a separate force and not as a quality of the hydraulic water. The idea of the shaking classifier then suggested itself. In this, an eccentric motion imparted to the classifier box would act as a disentangling and transporting force, while non-pulsating hydraulic water would

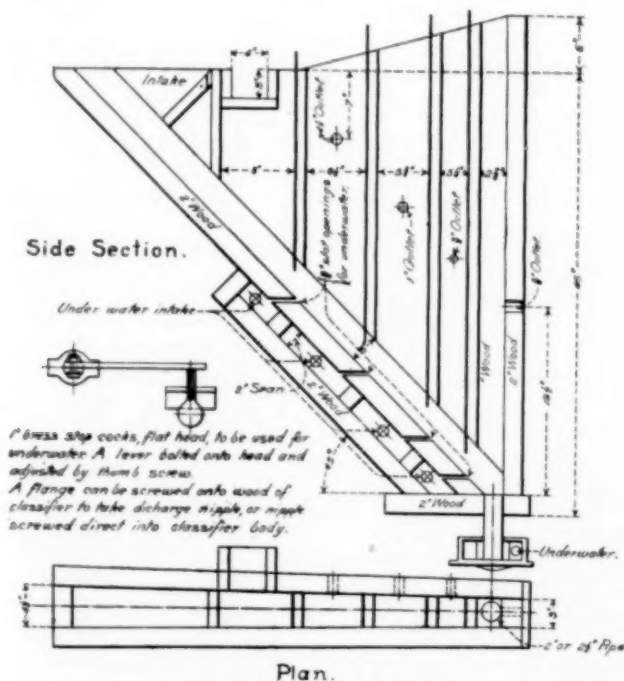


FIG. 1—HENDERSON CLASSIFIER

the bed of ore along the supporting screen; (2) forming a more uniform bed of ore on the screen; and (3) making the device less sensitive to variations in feed. The first of these conditions was realized in a classifier designed by Mr. R. M. Henderson, manager of the Wellington Mines Co., Breckenridge, Colo. This classifier was described in METALLURGICAL AND CHEMICAL ENGINEERING, November, 1910, page 621. It is shown in plan and side elevation in Fig. 1.

In this classifier the hydraulic water is without pulsation, the feed flows by gravity down the 45 deg. inclined-bottom of the box and is acted upon by the streams of hydraulic water issuing through horizontal slots in the bottom. The first compartment receives no hydraulic water and gives an overflow of slime. The succeeding compartments receive increasingly stronger currents of hydraulic water and yield increasingly coarser products. The sixth product issues from a vortex sorting col-

*Part of a paper read before the Colorado Scientific Society, Denver, entitled, "A Critical Discussion of the Richards Pulsator Classifier." The original paper gives in detail the results of the author's investigations which led him to evolve the design of classifier presented in this abstract.

furnish the necessary sorting-column water. I tried to design a machine so as to shake the screen independently of the classifier box, but came to the conclusion that stuffing boxes would be too difficult to maintain; and, in addition, found an advantage in shaking the material in the sorting columns.

In the Richards pulsator classifier, the pulsating force is applied practically vertically in an attempt to keep the ore bed free and open, and to disentangle the pulp in the sorting column. It occurred to me that a shaking motion applied horizontally would more suitably maintain the ore in condition to be acted upon, by aiding materially in transportation, and that disentanglement in the sorting column would be more pronounced by a sidewise impulse than by a vertical.

The result of this study and experiment is the evolution of a classifier of the following description. See Fig. 2. A box adapted to be shaken longitudinally is divided into six vertical compartments, "C₁" to "C₆" with an inclined screen "S" placed between the compartments and the corresponding hutch "H." The inclination of the screen is not more than 15 deg. Hydraulic water without pulsation is introduced into the hutches, the velocity being regulated suitably for each compartment. The screen, so called, is in reality a miniature grizzly made of spring-brass bars 1/40" thick, spaced 1/40" apart. The space blocks are so placed as to come directly beneath the compartment partitions and thus avoid the formation of bare spots at those points. As mentioned before, the discharge openings in each compartment are arranged so that the head of water in any compartment is about one inch higher than in the preceding one.

In operation, the ore pulp is fed in the usual manner, and falls onto the inclined screening surface "S." The shaking motion tends to act strongly upon the heavy particles and less

strongly upon the intermediate, so moving them at the desired velocities along the inclined screen, while the fine tends to remain behind. By using an inclination of only 8 deg. I tried to stratify the material as nearly as possible with the idea of picking off the lighter supernatant layers; but I found that the more nearly the screen approached the horizontal, the poorer the classification became; and that trying to use little hydraulic water in No. 1, more in No. 2 compartment and so on caused "banking up," variable distribution to tables and constant changes. When I arrived at an inclination beyond 15 deg. I found that, for our ores (silicious lead and zinc sulphides), the coarse material rolled down the screen too fast, with the shaking type, and that too high differences of head in the sorting columns would have to be maintained, i.e., the head in, say No. 6 compartment would be nearly three inches higher than in No. 5. This caused a too violent cross-current underneath the opening "F," so tending to disturb the quiet conditions sought. Since the difference between the greatest inclination necessary and the least is only some five or six degrees, this adjustment may be provided for by raising or lowering one end of a standard design.

Since building the shaking classifier I have found that it would have been better not to design the machine with the screen at one continuous inclination, but to put the screen on a curve, or with a slight angular change in each compartment as shown in Figs 3 and 4. No water at all is needed under the feed compartment or under No. 1, as the overflow from No. 1 is the fine material that would not in any case quickly settle to the bottom of the feed compartment, but is held in suspension in the water fed in with the pulp and overflows at "D₁". At "C₁" the screen inclination should be pitched at a sufficiently

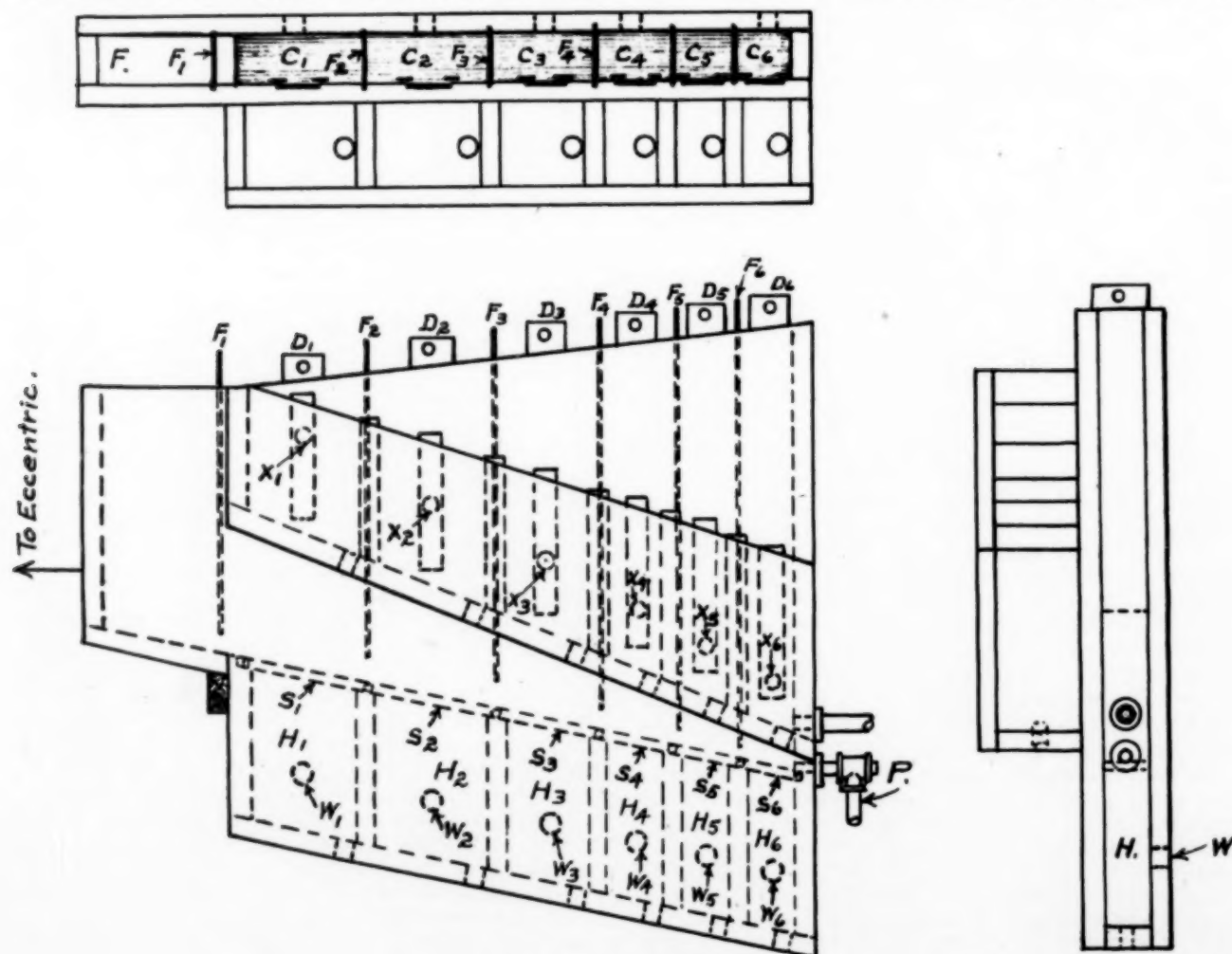


FIG. 2.—SHAKING CLASSIFIER.

steep angle to allow of the easy flow of the pulp which does settle. In falling through the column of water in the feed compartment and by being acted upon by this feed water rising, all the sorting effect that can be hoped for is had on the material (slime) which rises in "C₁." Slime pulp may be considered almost as a fluid for all practical purposes in ore dressing. At the No. 2 compartment the screen should have a slightly lesser pitch from the horizontal, as it is desired to retain coarser particles than those composing the slime in No. 1. At "C₂" the angle should be less than "C₁," as it is apparent that there is also a decreasing amount of ore as we pass along. The distance on the screen is less and we wish to retain certain sizes

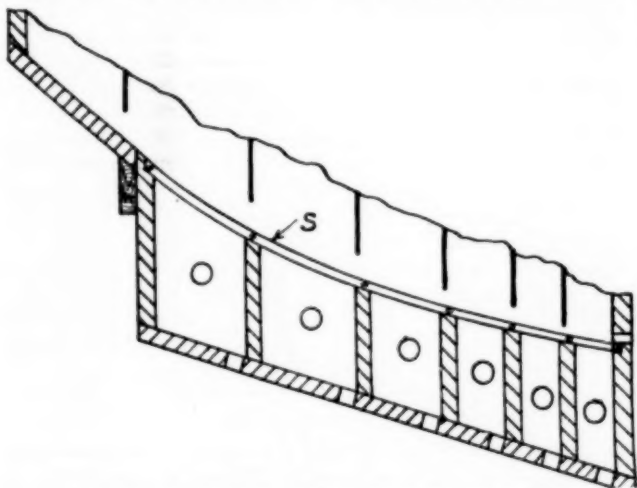


FIG. 3.—SHAKING CLASSIFIER WITH CURVED SCREEN.

continually growing larger which can remain behind at decreasing inclinations. In other words, the angles in each compartment should be steep enough to allow gravity to carry from it that material not desired in that compartment, without any need for water transportation; and at the same time it should not be so steep as to tend to cause those to roll away which should properly rise.

For classification I have found that the principle applied in magnetic work, that of selecting material from a layer "one particle thick," is much to be desired over that in which bedding or stratification is used, with a lifting off of supernatant layers. In the latter case there is too much tendency to entanglement. Further, with the "one particle thick" idea the hydraulic water may issue through all parts of the screen area in a given compartment at equal velocity, as there is not that resistance due to banks of ore, compelling the water to come through small parts of the screen area at a higher velocity than that in the sorting column above, and so blowing up oversize into this sorting column. It has actually worked out with the machine now installed that there is some accumulation on the screen in compartments 1 and 2, showing the necessity for increased inclination here. As a consequence, we have to use a little too much hydraulic water; but farther on the ore passes along so that there is no appreciable accumulation. I tried using a little more hydraulic water under Nos. 1 and 2, to prevent any apparent accumulation, but found, as I expected, that more oversize material would be discharged on account of the disturbance. Now, if the angle were greater, even less hydraulic water could be used in the finer size compartments than now, and better work had.

In regulating the inclined-screen shaking classifier, there is no damming of ore or "banking," and a proper regulation would be as follows: First, admit the pulp of as thick a consistency as possible; regulate the discharge slides so that the holes are as high as possible on No. 1, and as near the screen as possible on No. 6 compartment. These discharge holes, on a 6-compartment machine will run from $\frac{5}{8}$ " diameter on "D₆" to about $1\frac{1}{4}$ " on "D₁" with the intermediate holes in proportion, the machine

handling 50 to 100 tons per day. In passing it might be well, however, to call attention to the fact that the larger holes "X" at the first compartments will not actually discharge as much water as will the smaller at the back end owing to the difference in heads in the sorting columns.

The hydraulic water should be so regulated that no appreciable amount of ore can be felt on the screen. If this occurs, more hydraulic water must be used at the compartment where the bed has accumulated. If the screen is so bare that the small particles cannot be felt rolling down to the last compartment, some hydraulic water should be turned off. This should result in a proper division of pulp to the tables or other separating devices. Also, there should be a gradually reduced opening of the hydraulic water valves from "W₆" to "W₁," "W₁" opened little if any. Whether this has been properly performed may be checked by the result that there should be about an inch increase of head in each compartment from "C₁" to "C₆." If oversize shows on any table the gate "F" between its compartment at the classifier and the next below should be raised to allow this oversize to pass.

If, on account of the average screen analysis, the arrangement should not show definite progressions in elevation of the discharge openings "X," the holes "X" should be made larger or smaller to allow of a larger or smaller amount of sorting-column water to discharge. I have found it almost imperative on our ores, if a vortex sorting column is not used at the last, to have a seventh classification discharge from the screen level at "P." At the end of the classifier above the discharge opening "P" we have a $\frac{1}{2}$ " pipe connected to the water supply. This is for use of the workmen who may open it to throw on a little more water when the supply of ore is a little coarse and to shut off when there is a considerable amount of fine. This pipe valve, when opened and closed, possibly once in several days, saves the other adjustments from disturbance when once satisfactory. I have run for months without finding any need of change, as the sorting column velocities have the same effect on a given size, and the effect of gravity rolling a particle down the screen to its proper compartment is practically the same whether the tonnage is large or small.

Of course, the pulp delivered to the tables will be more or less diluted in proportion to the tonnage fed, with the classifier water remaining uniform, but all the tables receive their pro-

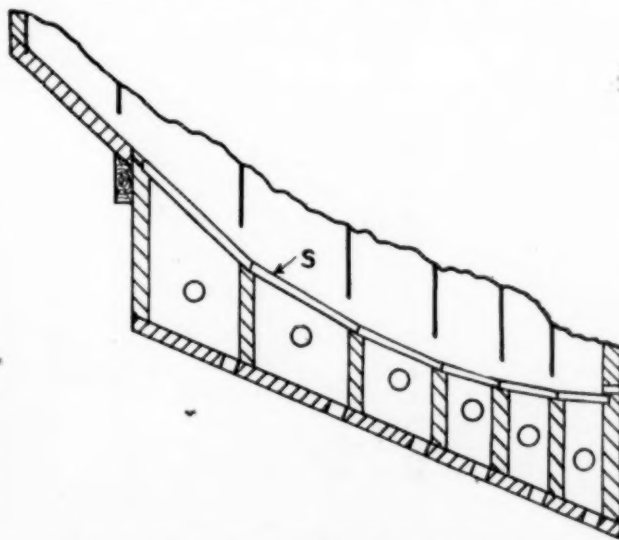


FIG. 4.—SHAKING CLASSIFIER WITH CURVED SCREEN.

portionate amounts, and do not vary back and forth between the fine and coarse tables, as in a classifier where the tonnage and other variables determine the overflow in the different compartments.

To sum up: The machine itself is automatic or "fool proof," which, in any machine, is greatly to be desired. There is not

the necessity for continual adjusting by an expert to take care of variation of operation. Close adjustments may be made, and these only tampered with when the valves clog or changes are necessary from wear.

After having this design in mind for some time, I suggested its use to Mr. R. M. Henderson, and he built and installed two machines working on the inclined-screen and shaking principle. He informs me that the first installed did excellent work and

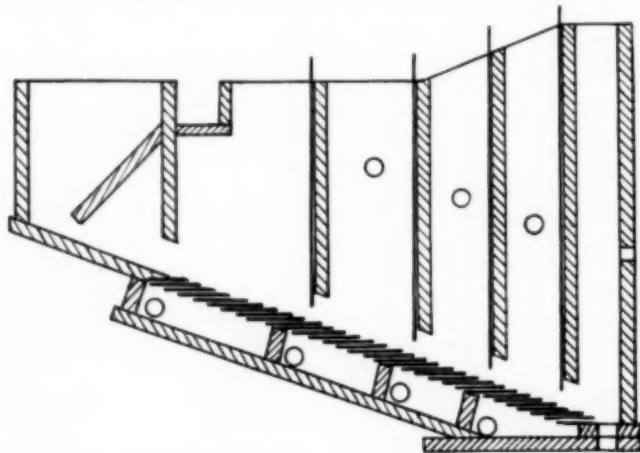


FIG. 5.—SHAKING CLASSIFIER WITH MODIFIED SCREEN SURFACE.

that in his experience, he had never seen as good classification. The second classifier which he built at the Wellington Mill, was not so successful, due to his alterations in design of the perforated screening surface which tended to mix and disturb the ore. See Fig. 5. The falling from step to step as shown in this screen surface is objectionable, as will be seen if studied from the foregoing arguments.

Western Chemical Mfg. Co., Denver, Colo.

Belt Conveyors*

BY LINCOLN DeG. MOSS.

During the war with the Seminole Indians, biscuits for the troops were baked at St. Augustine on a machine invented by W. R. Nevins of New York City, who employed an endless canvas belt conveyor running on flat idlers. During the 60's the Choice & Gibson brickmaking machines employed flat, endless belts to carry molded bricks from the pug mills to the stacks for baking. In the same decade Cook's magnetic ore separator was used at Plattsburgh, N. Y., for carrying ore from a vibrating hopper under a revolving magnet which left the rejected material on the belt to go to a waste pile.

Some eminently practical work was done by Lyster at the Liverpool (England) docks, described in the *Proc. Mech. Engr.*, August, 1869. Finding that spiral conveyors in troughs lacked capacity and used a large amount of power, he experimented with endless bands. He developed several essentials, such as the "throw-off carriage," or tripper, so arranged that the dumping pulley could fold down and stop the throwing off of grain; a tripper which could discharge right, left, or back on the belt; the tension take-up; an endless, rectangular circuit with loading chutes and trippers on upper and lower levels. He also used rotary cleaning brushes and an air-blast brush. His tests showed that the helical conveyors required four times as much power to carry 50 tons per hour 100 ft.

He first used concentrating rollers, Chart 1, Fig. 1, to increase the carrying capacity of the belt, which had two plies of canvas covered uniformly with vulcanized rubber. He abandoned this carrying idler, using thereafter 6-in. straight, turned, wooden rollers, because the difference in circumferential speed at the body and rim of the concentrator roll caused a

slip at the rim which wore out the belt edges. A point on his belt, which moved 8 ft. per sec. for 10 hours per day and 300 days per annum, would travel yearly over 86,000,000 ft. The central, 6-in. diameter of the roller governs, as it carries the major part of the load. At the 9-in. part of the cone the slip would be over 43,000,000 ft., which explains why his belt edges wore out. With the flat, cylindrical idlers used thereafter, which was the older American practice, he used two diagonal rollers, Chart 1, Fig. 3, to concentrate the load in the center of the belt at loading points.

In this country the Webster Manufacturing Company carried on such work for many years. Early in the 90's iron ore was carried in the Edison mines of New Jersey on belt conveyors. Scraper conveyors had been abandoned, owing to rapid wear. Belts of cotton and of cotton with a rubber cover were used. Concentrator idlers were tried and abandoned, as in England. Flat belts with continuous skirt boards followed, with this fault: Particles of ore got between the belt and the skirt board near the center of a span between two idlers, where the belt sagged under the load; these particles, lodging, cut the belt edges, in time destroying them when the skirt boards were moved in to accommodate the narrowed belt. When skirt boards are used at chutes their lower edges should be a thin sheet of steel, which will not permit a lump to remain long.

Next we note the experiments of Thomas Robins at the Edison plant. Not knowing the researches of Lyster, he learned the same truths. He tried two inclined concentrator rolls, and found that the belt did not "steer" true, but rolled into the apex of the angle at the two pulleys, cutting the belt. The next step was to add a third pulley set horizontally and in the wake of the two concentrators. (Chart 1, Figs. 7-8.)

Oil lubrication gave trouble, as some oil threw out centrifugally on the belts and ate holes in the cover. This must be carefully avoided when using idlers lubricated by oil. Although friction is greater with grease lubrication, Mr. Robins adopted it thereafter, using fixed hollow shafts, with the opening at the center of bearings. This formed collars of grease at the ends of the journals and made a perfect dust guard in the worst situations. Not only is this desirable for idlers in such service, but it is excellent for the main bearings of head and tail rollers, using solid shafts. Several very effective oil lubricated idlers are now made with dust guards.

The belts at first had a cover of uniform thickness, top and bottom. Mr. Robins next built his belts with a thicker carrying cover. This belt is now patented and is in very general use. Then noting that these new belts wore away faster in the center, he made still thicker center, either straight or tapered to the edges. He next made a belt like Chart 3, Fig. 2, which was very flexible in cross-section and had stiff edges to support the catenary between two idlers. His idlers finally were built in one plane, like Chart 1, Fig. 9.

The angle of inclination of the wing idlers was 45 deg. This caused too great a flexure on the belt and actually reduced its carrying capacity, which is maximum at about 30 deg. inclination. (See Chart 3.) An angle of 30 deg. is the maximum used at present, although some old installations using steeper angles are very successful. Troughing a belt has a commercial bearing by increasing its carrying capacity and decreasing the wear caused by the materials. A given quantity of material loaded on a wide belt will be shallower in depth and will cause more wear than when a narrow layer is applied and the rest of the load superimposed upon the first protecting stratum. Troughing such as can be secured by the natural flexure of a belt, without forcing, is not injurious. Belts of ordinary uniform construction will give a considerable natural trough when 24 in. wide and upward. Heavy belts are naturally stiffer than thinner ones.

A rubber belt is not homogeneous, being built up of a number of plies of cotton duck cemented together, under heavy pressure, with rubber. Makers call this the "friction." The built-

*Part of a Paper on Mechanical Conveyors in the *School of Mines Quarterly* (Columbia), April, 1912.

up plies are finally covered with rubber, and vulcanized under pressure. Much of the success of a belt depends on the "friction" between the plies. The purer the rubber used, the better the adhesion. This is usually tested by cutting a ply loose, 1 in. wide, hanging the belt vertically and attaching a weight to the loose strip, adding to it until the weight will just peel

plies. Bending over pulleys is of more consequence than the bend of troughing, as the radius of pulleys is much less than the radius of the trough, and a belt is stiffer along its length than transversely; this is due to the construction of the canvas, which has long continuous longitudinal fibers, unbroken for as much as 400 ft., while the transverse fibers and threads are

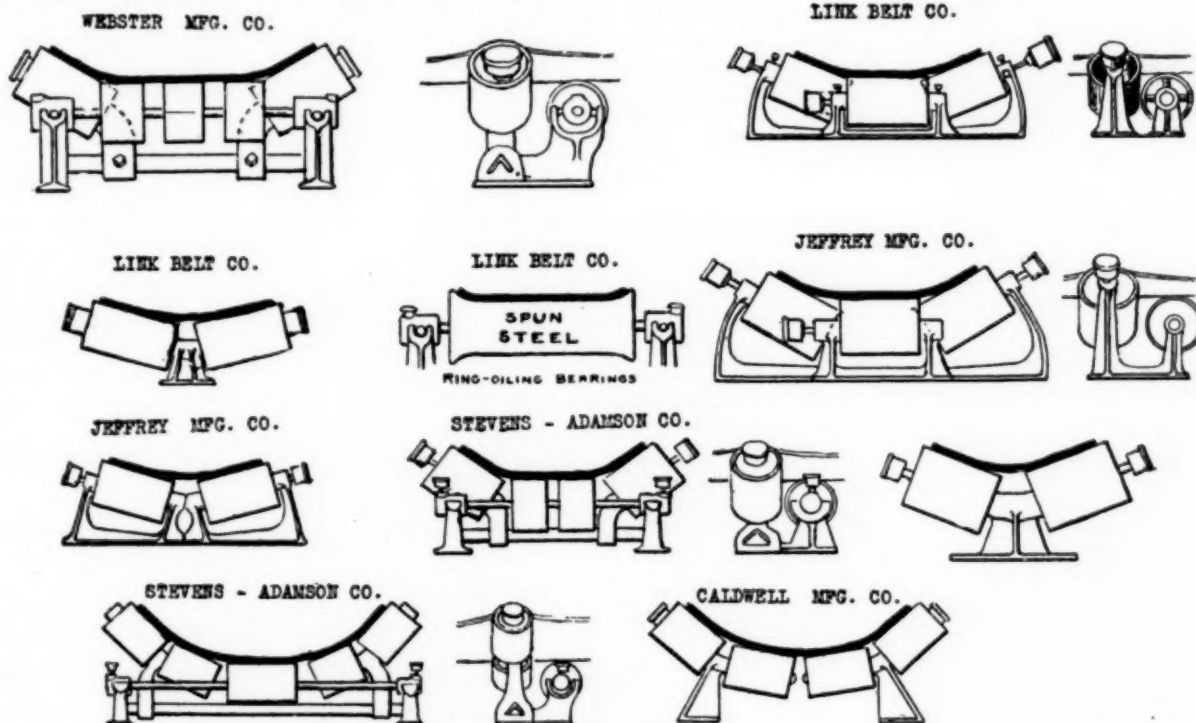


CHART 1.—EVOLUTION OF BELT CONVEYORS.

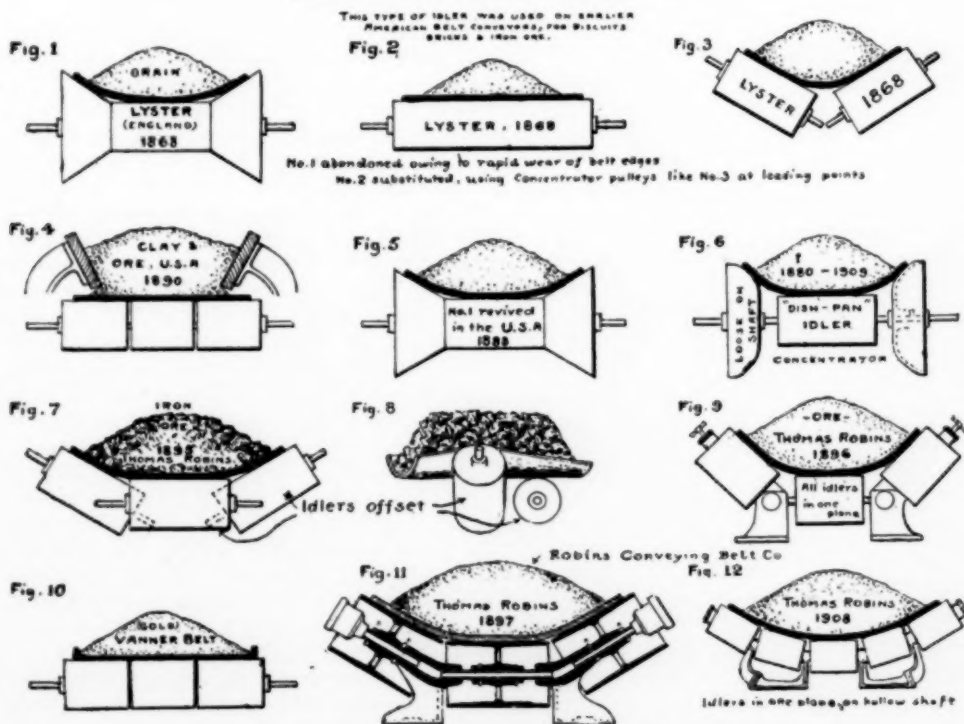


CHART 2.—EVOLUTION OF BELT CONVEYORS.

the strip loose. This value ranges from 7 or 8 lbs., with inferior belts, up to 26 lbs.; 16 lbs. is excellent.

As the belt bends over either end or tripper pulleys, or transversely by troughing, forces tending to separate the plies are set up, resisted by the elastic, tenacious rubber between the

durability is poor and the consumer has specified details of construction he becomes more or less liable.

The durability of a belt depends much on the manner of loading and operating; another factor is length. For a given output and speed, a spot on a belt 100 ft. long will come under a

short, not quite as long as the width of belt, fewer in number, and disconnected.

The wearing cover, for commercial reasons, is compounded with other materials to lessen cost. Success lies in skillful compounding, which will not depreciate the wearing quality to a marked extent. The percentage of adulterant can be found by burning a strip of rubber and noting the residual ash; pure rubber leaves none. A good friction test is valuable. The use of high-grade, long-fibered cotton duck adds tensile strength and increases cost. Tensile strength is not a prime requisite, especially at the high speeds of transmission commonly adopted. Some experts judge the quality of rubber by its taste, but that cannot be formulated. It is safer to trust a reputable maker whose reputation is at stake than to specify how he shall make a belt, for in case the

loading chute twice as frequently as on a belt 200 ft. long and sustain twice the wearing effect of loading. If the chute delivers the material at a fair velocity, in the direction of the belt travel, the wear of loading will be reduced. If the material is fed in a thin, intermittent stream, the rubber cover will suffer much more than if the load is fed on continuously and the belt trough kept full. In the latter case, only a small percentage of the material ever touches the belt. Hence the important rule that a belt should be so proportioned to its load that it will be kept full, and operated at a speed which will require it to run full. When belts are installed with reference to future increase of carrying capacity it is better to operate at first at a low speed, and then change the gear ratio for higher speed at the larger output.

If the material carries a fair percentage of fines, such as crushed ore, it is well to arrange chutes as made by Thomas Robins in his early work in conveying iron ore. These chutes had grills or screens which dropped the fines on the belt,

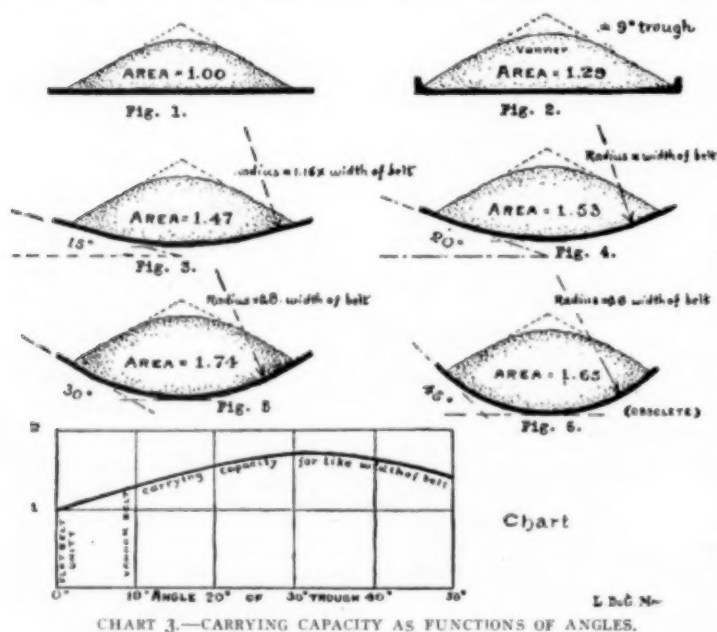
ores, 500,000 to 1,000,000 tons; sand, ashes, and coke follow in that order, coke being the most destructive. The belts are not suited for materials hotter than 150 deg. F., nor for carrying oily substances. They resist water, gases, alkaline or acid ashes, wet cement, and common salt. Many operate entirely exposed to the elements, in hot and cold climates. They resist abrading materials to a remarkable degree. They are not entirely waterproof, for the following reasons: Assume a dredge belt carrying wet tailings of gravel and stone. Fibers of the outer plies of cotton duck project up into the rubber cover, which is put on in a plastic state. The cover, when new, would be $\frac{3}{16}$ to $\frac{1}{4}$ in. thick. As it wears down, these small fibers of cotton carry water into the body of the duck, setting up rot and separation between cover and canvas. Some sharp pointed stones may penetrate the cover down to the canvas and hasten this action.

In the South African mines, considerable balata belting is used for handling wet materials. The belt is composed of cotton duck cemented by balata gum applied at the consistency of milk, under heavy pressure. No vulcanizing is necessary. The heaviest duck used with rubber belting is 32-oz., open weave, to permit the plastic rubber to pass through and bond. With balata belting a 36-oz. duck, closely woven, may be used because the thinner, milklike juice will pass through more readily. For this reason, and also because no heat is used, which diminishes the strength of duck, balata belts are relatively one-fifth stronger. Several oils will dissolve balata gum which is obtained from the Dutch East Indies. The proper mixture of solvents and their elimination after the belt has been made, are trade secrets. It would seem that a belt having a homogeneous, waterproof, balata and canvas core, with a wear resisting rubber cover, would be an ideal conveying belt, provided that a stout bond can be made between the two materials.

The spacing of the troughing idlers should bear a relation to the weight of material on the suspended span between two adjacent idlers. The minimum spacing for heavy ores is $3\frac{1}{2}$ ft.; for coal, $4\frac{1}{2}$ to 5 ft.; for light materials, 6 ft. Return idlers carrying the slack belt may be set 10 to 15 ft. apart. The diameter of pulleys should bear a relation to the number of plies in the belt, just as we use certain ratios of rope diameter to sheave diameter. Other considerations enter. The larger the diameter of driving pulleys the lower the speed becomes, necessitating a larger and more wasteful gear reduction between pulley and motor. It is often difficult to arrange a delivery from the head pulley to the tail of another conveyor, even with small pulleys, and get satisfactory chutes.

Driving pulleys are generally made larger than tail pulleys and tripper pulleys. For rope transmission it is considered that all pulleys, whether drivers or carriers, should have like diameters, if the maximum life is to be obtained from the rope. At the driver the extension of the fibers is that due to driving tension plus the extension due to bending around the wheel. Thousands of belt conveyors are running with pulley diameters of 4 to 5 in. per ply of belt. We consider that a ratio of 6 in. per ply would be preferable if local conditions permit.

A head drive is cheapest and most desirable as a rule. Tail drivers are frequently used, especially when two conveyors are to be driven, one at its head, the other at its tail pulley, by a common motor. The journal pressure on the head shaft of a tail-driven conveyor will be twice that of one driven at the head. Center and intermediate drives are much used, but require more mill work than head or tail drives. It is generally preferable to drive a boom conveyor from the tail end. For heavy driving some very successful installations employ a modification of the old letter S American rope drive. The same principle is used in some Koeppel mine hoists, with two tan-



making a bed over its carrying surface to receive the large chunks. Badly arranged deliveries may destroy a belt in less than a week. The best record for durability which has come to my notice is at Louisburg, Canada, in the ship loading trestle of the Dominion Coal Company. Coal is accumulated in a 5,000-ton pocket by railway gondolas and is drawn off by a series of 36-in. Robins belt conveyors which elevate the coal to loading spouts which fill the hold of a 3,000-ton collier in four hours. The belts run at about 700 ft. per minute. The coal is bituminous, with few lumps. The present belt has carried over 3,000,000 tons and is good for more service. For steady, hard service we quote the conveyors of Jones & Laughlin, which supply their Eliza furnaces at Pittsburgh, Pa. The record for one year showed that the conveyor ran for 363 days, 9.2 hours per day, and transported 500 tons per hour. This is a Robins installation.

For a wide range of service, the plant of the New Jersey Zinc Company, at Franklin Furnace, N. J., uses over 200 belt conveyors which handle franklinite (a trifle lighter than galena) from man-size rock down to finely crushed sands, which pass through Wetherill magnetic separators. Many of these conveyors operate in clouds of heavy, gritty dust, which shut out view at a distance of 3 ft. The conveyors are Robins. Those used in the magnetic separation run on bronze pulleys. The hot sands are carried on canvas belts; the wet sands and rock are moved on rubber and canvas belts.

For coal, a life of 1,500,000 tons may be anticipated. For

dem rope sheaves. This drive was first used on a 36-in. Robins conveyor 1050 ft. long between centers, which had a stacking tripper connected with it. This machine was used for filling in swamp land at Riker's Island, New York City, with ashes and dry city refuse. The drive transmitted 80 hp at the tail end, and has since been widely used.

Driving power is measured by (1) arc of contact; (2) tension; (3) coefficient of friction, in the same way that friction drives for Whiting or Koeppel hoists, cable drives and traction elevators are determined, using Rankin's formulas for endless bands. The arc of contact may be increased by using a snub pulley behind the driver. In most examples this snub pulley is entirely too small. The letter-S drive will give twice the arc of contact obtained by a snubbed driving pulley. In driving cables with two drums, the leading drum performs over two-thirds of the work. That is probably true of the letter-S drive applied to belt driving.

The coefficient of friction may be raised from 0.2 to 0.3 by lagging the pulley face with rubber belting bolted to the pulley face with countersunk bolts. Some slippery materials will decrease the coefficient of friction, the fine dust getting between the pulley face and the belt. Water also reduces the coefficient of friction, which explains why we have quoted 0.2 and 0.3 for designing.

The working tension should not exceed 20 lb. per inch width of canvas per ply, nor should it exceed one-fifteenth the ultimate strength on account of the splices, which are made preferably by butting the belt ends together, holding the two ends by tension belt clamps, and connecting with Crescent or Bristol steel belt hooks. It is advisable to pierce the holes with a sharp tool before driving in the lacings, which are clinched on the inner side. Patches may be put in by the same method. Mr. Lyster in 1868 discarded pneumatic sweeping because it required much more power and wore the belt; he therefore used a rotary brush, which was not altogether satisfactory. That holds true to-day. In moving damp materials, when cleaning is most desirable, the brushes clog and do little effective work. A water jet spray has been used when moving wet concrete.

Trippers may be fixed, movable by hand, or moved by power derived from the belt. Fixed trippers require more power, in proportion to the number used, and are justified in few cases. For example, if colliers are to be loaded, taking coal simultaneously at bow, midship, and stern hatches, a fixed tripper at the first and second fixed point and one end delivery for the third point would be the most economical arrangement, the first tripper taking off one-third and passing two-thirds over to the second tripper, which would take one-third and pass the remainder to the end pulley. Over a boiler house bunker, however, with three fixed trippers, and dumping at one point at a time, the coal would be lifted over each preceding tripper and dropped back on the belt, causing needless wear and wasted power.

A hand-propelled tripper running on T-rails will answer in most cases, for, as a rule, trippers are not run back and forth to spread the material, but are clamped down to the rails to build a conical pile and then moved a few feet so as to deliver on the crest of the cone. The extra expense of automatic trippers is often unjustified. The framing of a tripper should be very stiff and substantial, for if elastic the two belt pulleys in the tripper will deflect and cause the belt to run to one side. To correct a tendency to run to one side along the line of the belt, the idlers should be arranged to be canted, by slotting the feet of the pedestals at the bolt holes. Side-guide idlers should be used as little as possible to avoid wearing the belt edges. It is better to train the belt by canting the idlers and end pulleys.

Power Capacity and Efficiency of Belt Conveyors.

Up to the present time these factors have not been well understood, for two reasons: (1) This form of conveyor has

been in general use for heavy work, for little more than twelve years, since it was made practical for coarse and heavy materials by Thomas Robins. (2) The engineers concerned in its development have had little time to spare for analysis of the phenomena of this interesting transporter. To aid in clearing up these questions I have prepared Charts 3, 4, and 5. When we cease to generalize, and group observations and data with care, consistent curves of performance, power, and efficiency can be plotted.

For uniformity I have referred efficiency back to the motor input, which can be measured by the wattmeter at the motor

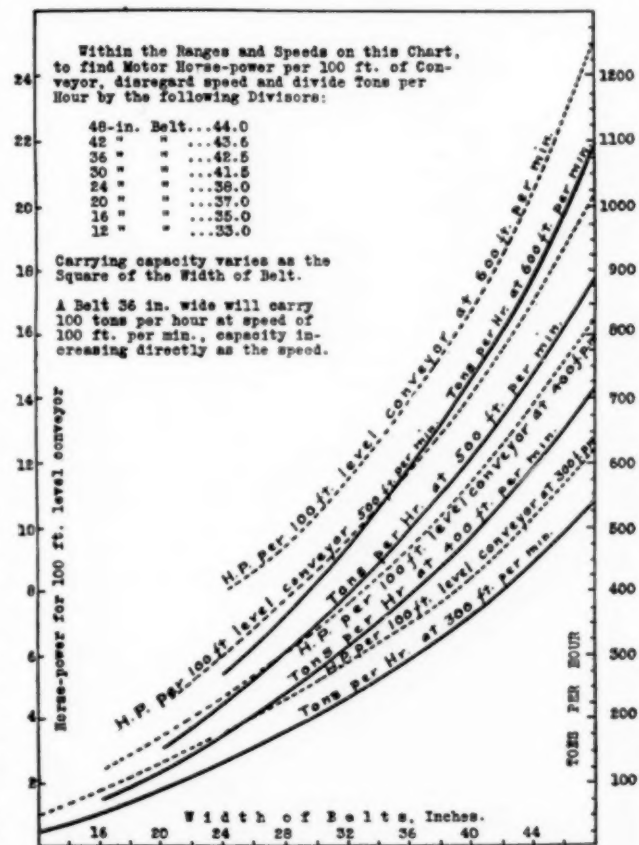


CHART 4.—CARRYING CAPACITY IN TONS PER HOUR.

Materials weighing 50 lbs. per cu. ft. Belts troughed to 30° from horizontal trough section equivalent to 1.7 that of flat belt. Also horse-power per 100 ft. of level conveyor. Grease lubrication. For each fixed tripper add 5%, but not less than 0.8 hp. For movable tripper add 6%, but not less than 1 hp. For lifting on inclines add tons per hour \times feet lift \div 900.

terminals, and is equivalent, as nearly as possible to the indicated horse-power of a steam engine. This seems more just than to disregard the friction loss in the gearing between conveyor driver pulley and the motor, and to omit the inevitable losses in the motor, as some writers have done.

The great effect on efficiency due to varying density of the materials carried has been generally overlooked, which is also true of observations on conveyors carrying very light loads. One gentleman has stated that his conveyor consumes 90 per cent of the total power in friction; he was without doubt correct. For example, a certain conveyor has a 30-in. belt, 386 ft. long on its carrying side, moving 348 ft. per minute, and carrying 40 tons per hour. It used 13.4 hp with no load and only 14.0 hp when fully loaded, showing 96 per cent friction loss. Another gentleman has a 30-in. conveyor, 400 ft. long, moving 400 ft. per minute and carrying 600 tons of ore per hour. The light power was 15.3 hp, which rose to 33.7 hp when carrying full load, giving a friction loss of about 46 per cent. Each observer was correct. The power required to run a given conveyor with no load, is exactly the same, regardless

of the quantity and density of the material to be fed to the belt, whether it be feathers or galena. But the friction loss in handling a load of feathers would be over 99 per cent, and would fall to less than 40 per cent when carrying galena on the same conveyor.

The wide discrepancy in the efficiency of the two 30-in. conveyors referred to can be further understood by studying Charts 5 and 6. The performance of a 36-in. conveyor, 100 ft.

and driver pulley of the conveyor. The gear-reduction loss depends on the quality of materials, proper proportions, with accurate lining and leveling of boxes, and the gear ratio. If the driving pulley is large, the belt speed is low, and the motor speed high, with bearings not proof against grit, the gear reduction loss may reach 40 per cent, and rarely falls below 15 per cent. The conveyor by itself will show 30 to 50 per cent friction loss at the driver pulley.

These charts, I hope, will prove valuable to the profession. Their use will save time in calculations, which require cum-

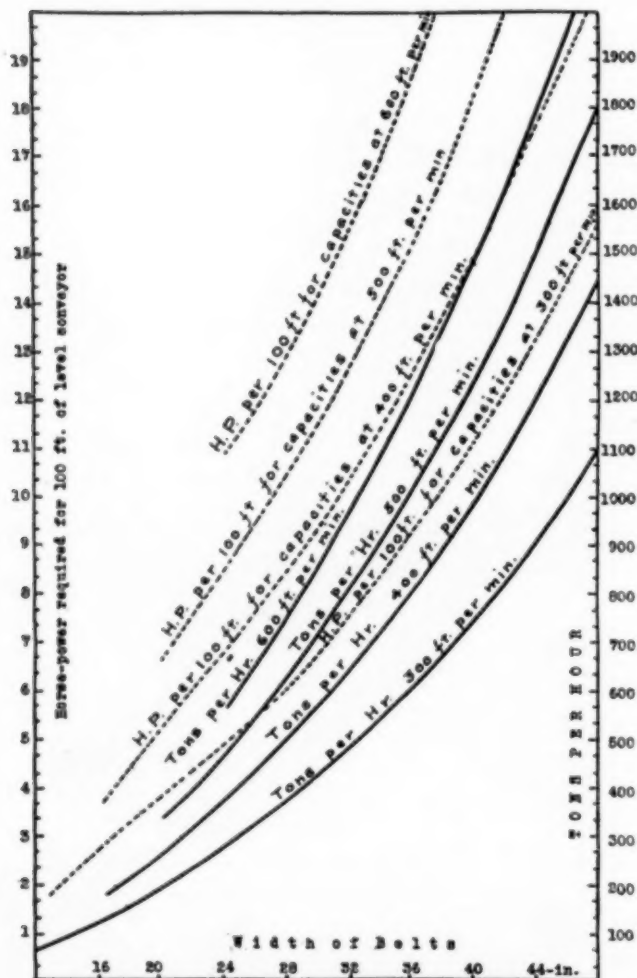


CHART 5.—CARRYING CAPACITY IN TONS PER HOUR.

Materials weighing 100 lb. per cubic foot. Belts troughed to 30° from horizontal; trough section equivalent to 1.7 that of a flat belt. Also horsepower per 100 ft. of level conveyor. Grease lubrication. For each fixed tripper add 5%, but not less than 0.8 h.p. For moveable tripper add 6%, but not less than 1 hp. For lifting on inclines, add Tons per hour \times Feet lift \div 990.

Carrying capacity varies as the square of the width of belt. At every speed in the range on Chart 5 with materials weighing 100 lb. per cubic foot, for every 100 ft. of level conveyor, the following horsepowers are required:

| | |
|-------------------|-----------------------------|
| With 48-in. belt, | H.P. = T. P. H. \div 70 |
| " 42 " | " H.P. = T. P. H. \div 67 |
| " 36 " | " H.P. = T. P. H. \div 64 |
| " 30 " | " H.P. = T. P. H. \div 61 |
| " 24 " | " H.P. = T. P. H. \div 54 |
| " 20 " | " H.P. = T. P. H. \div 50 |
| " 16 " | " H.P. = T. P. H. \div 50 |
| " 12 " | " H.P. = T. P. H. \div 50 |

long, at speeds up to 600 ft. per minute, is shown, first, when carrying materials weighing 100 lb. per cubic foot, and, second, when carrying materials weighing half as much. For comparison, the performance of a 20-in. conveyor is shown just beneath, handling materials of the same weights per cubic foot.

The total power loss when handling materials weighing 50 lb. per cubic foot is about 70 per cent for either 36-in. or 20-in. conveyors. Of this, about 15 per cent is lost within the motor, and 15 to 20 per cent more in the gear reduction between motor

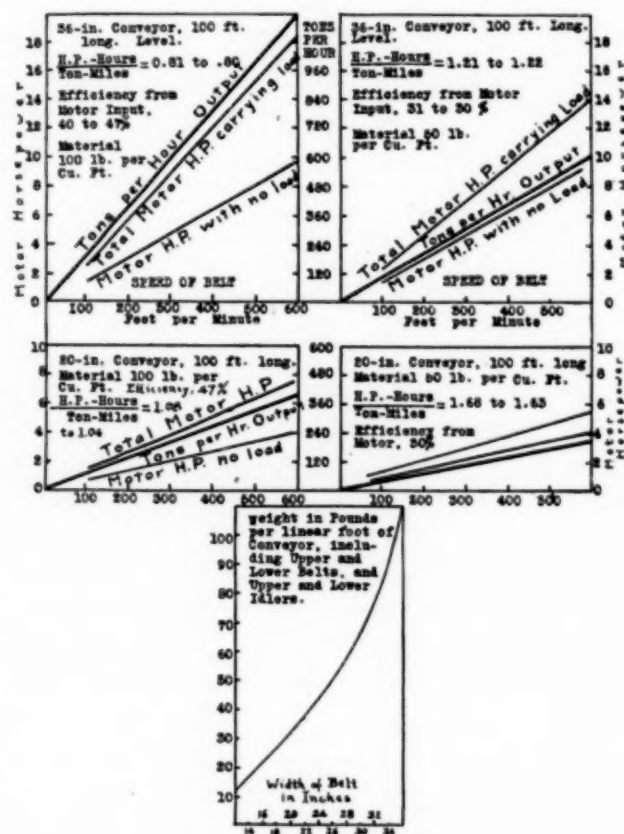


CHART 6.—EFFICIENCY OF BELT CONVEYORS.

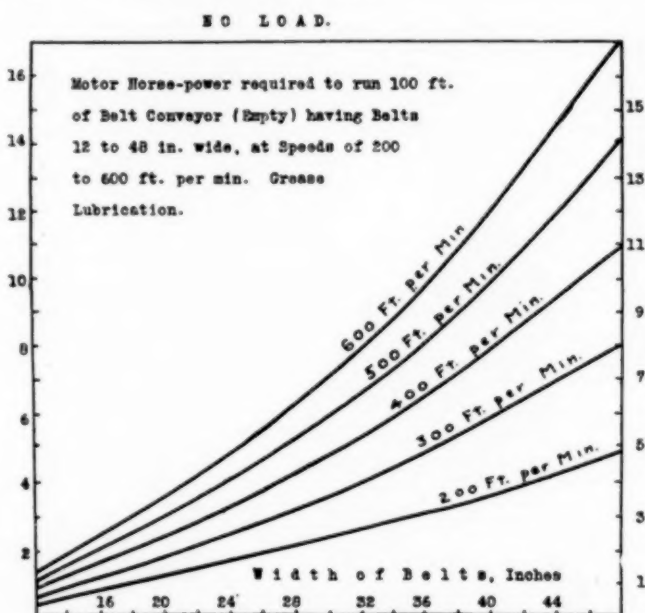
bersome formulas, made in some cases from incomplete and inconsistent data. Carrying capacity may be found by simple inspection for belts from 12 to 48 in. wide at speeds up to 600 ft. per minute. For a given belt, capacity varies directly as the speed, and in direct proportion to the increase in weight of material per cubic foot. For different widths of belts, capacity varies as the square of the width. The motor horse-power per 100 ft. of level conveyor may also be found by inspection. Allowance for grades may be added or deducted by the formula: $T.P.H. \times Ft. \text{ difference of elevation of receiving and discharging end} \div 990$. Allowance for trippers is made as noted on the diagrams.

The load-carrying cross-section is taken at the most economical troughing which can be obtained by the troughed belt, viz., 1.7 times that of a flat belt of equal width. (See Chart 3.) If flatter troughs, of less carrying capacity, are used, reduce the tons per hour shown on Charts 4 and 5 in proportion, referring to Chart 3. The horse-power will not fall in proportion, because a reduction in carrying capacity of trough does not affect the fixed friction at no load, and it is generally necessary to use a size larger belt to carry the required tons per hour. Data on conveyors having belts wider than 36 in. are meagre, but when properly used fall into the curves as shown. One exceptionally wide belt is in use, a 60-in. Robins, used as

a picking belt for separating barrels, mattresses, bed springs and coarse waste from city refuse.

Designers will find some handy short cuts to results noted on the charts. Especially interesting is the fact, which could not have been discovered without these performance curves, that the power required to operate a given conveyor, 100 ft. long, at any speed up to 600 ft. per minute, may be found at once by using a divisor into the tons per hour to be carried. These divisors for different widths of belts are noted on Charts 4 and 5.

By applying the ton-mile method of comparison we find the simplest of all short cuts. To find the power required to move a given tonnage we may ignore the size of the conveyor and its speed, and simply allow 0.8 to 1.2 hp-hour per ton-mile when the material weighs 100 lb. per cubic foot. For materials weighing 50 lb. per cubic foot, allow 1.2 to 1.8 hp-hours per ton-mile. The smaller figures apply to the largest conveyors, the higher constants to smaller conveyors.



Large Conveyors.
T.-M. in 10 hr. \times 0.08 to 0.12 = motor h.p., materials 100 lb. per cu. ft. at any speed.
Small Conveyors.
T.-M. in 10 hr. \times 0.12 to 0.18 = motor h.p., materials 50 lb. per cu. ft. at any speed.

To lift a load diagonally, belt conveyors may be inclined generally up to 21 deg. At steeper angles there will generally be a small slip backward, which is injurious to the rubber cover. On grades, an unbroken stream should be maintained if possible. Coal is elevated in one case on an angle of 27 deg. by keeping a steady flow from the hopper, which prevents the coal from slipping down. Cement fresh from the mills cannot be carried up an incline unless it is first passed through a short screw conveyor, which expels the entrained air.

The most conspicuous use of belt conveyors as elevators is in the New York subway power house, where coal is elevated by a series of Robins belts, arranged on the switchback principle, to the monitor over the bunkers. The shortness of these switchback conveyors, compared with the long tunnel conveyor and the long distributing conveyors over the bunkers, makes a noticeable decrease in their belt life, for reasons stated earlier.

In an ore mill which runs night and day, a 30-in. Robins elevating conveyor is in use for elevating 500 tons per hour of very heavy, sharp ore, reduced to coarse sand weighing 125 lb. per cubic foot. It contains a percentage of freshly broken quartz, very sharp and angular. This displaced a pair of first-

class bucket elevators, which gave much trouble owing to the large capacity, high strains, lift of 80 ft., and the rapid wear by the very abrasive sand. The angle is 23 deg., which should not have exceeded 20 deg., as there is an injurious slip on the belt cover. In this case the fall of a heavy bucket elevator meant a serious and expensive delay, whereas the belt gives signs of distress long before it will fail, and even if the belt pulled apart, the trouble would not be serious.

Generally, we believe that it is better to elevate by bucket elevator and distribute by belt. Belt conveyors have sometimes been improperly used as elevators. Elevating boom conveyors with 30-in. belts, on booms 80 to 90 ft. long, at angles of 20 to 22 degs., are in general use on Western gold dredges for carrying away the wet gravel tailings. A 36-in. Robins belt on a Danube dredge carries 1000 metric tons of gravel per hour. A barge with a reversible pivoted boom conveyor was supplied by the Link-Belt Company, of New York City. Another similar machine was built by the Webster Manufacturing Company for handling limestone on the Great Lakes.

When using the charts for estimating carrying capacity, allowance must be made for the size of lumps in the material. Mine-run coal from the West Virginia fields frequently contains lumps as large as a man's body, requiring a 36-in. belt. Ordinary mine-run bituminous coal has been successfully carried on 24-in. belts. Foundry coke requires a belt 30 in. wide, and ordinary coke a 24-in. belt. Belts for grain require about 4 hp-hours per ton-mile because the material is so light. An 18-in. belt will carry 50 tons per hour and will require 3.8 hp per 100 ft.

Structures for belt conveyors are light, owing to the lightness of the conveyor. (See Chart 6.) Trippers with stiff cast-iron frames range from 1000 to 3000 lbs. When trippers are used on trussed spans, do not forget to put in counters for the rolling concentrated load. Lateral stiffness is very important, to keep the idlers in line; otherwise the belt will not run true. Vertical deflections are of no consequence as regards the running of the belt. A continuous, dirt-tight deck over the return belt is very desirable. This may be worked out into a very stiff system of lateral bracing. A low house with hinged inspection doors is an economical method of covering. A walk alongside, for greasing, inspection and cleaning, is required. Many belt conveyors operate outdoors in all extremes of climatic conditions, with no covering. On exposed trestles, high winds may blow the light belt out of the troughing idlers. To prevent this, a low wind-break fence has been built up on one side, in a few cases.

A conveyor with ball-bearing idlers has been introduced by the Conveying Weigher Company of New York. The diameter of the idler pulleys is 2-3 that of other makers, as the friction is less. A conveyor for carrying coal has been in use for two years, and shows a reduction in power consumption of one-third. The bearings receive no lubrication, being greased with vaseline when first assembled, and closed with felt washers.

The use of aluminium in water purification was first suggested by Brandes and Neff, who took out patents and put their invention on the English market under the name of the "luminator." They claimed that water passed through a launder of aluminum exposed to sunlight was so affected as to cause little or no trouble from the formation of scale in boilers. This invention has been used at various places with greater or less degree of success, but no scientific explanation of the action has been made. Mr. William Cullen, past president of the Chemical, Metallurgical and Mining Society of South Africa, describes in the March, 1912, *Journal* of that society his experiences with a "luminator." He found that its use softened a very hard scale already formed in a boiler, and that the subsequent formation of scale was much reduced. The matter should be an interesting subject for scientific investigation.

Temperature and the Properties of Matter.

By E. F. NORTHROP.

Our understanding of what we term heat is a deduction from phenomena of which we have a direct sense perception. Heat is not directly perceived by any of the senses, but temperature is. In addition to the five senses ordinarily assigned, there is undoubtedly a true temperature-sense. This temperature-sense is more delicate than is ordinarily supposed. If you plunge your finger first into one glass of water, and then into another, you can feel that they are unlike in temperature if they differ by so little as $\frac{1}{4}$ deg. C. Our temperature-sense for which we probably have an independent set of nerve fibers, only enables us, however, to perceive accurately small differences in temperature; the absolute value of any temperature can be judged only very roughly and through a range of but a few degrees. In an analogous way the ear can perceive with great exactness small differences of pitch between two notes, but a keynote must be sounded upon an instrument to enable, in most cases, even trained singers "to get the pitch."

Since our temperature-sense is insufficient to furnish an accurate scale of temperature resort must be had for this purpose to some physical modification in one of the properties of matter which occurs in a regular way with temperature change. The physical means which has been most successfully adopted for establishing a scale of temperature is the change which occurs, when the temperature changes, in the pressure of a gas enclosed in a vessel of constant volume. It is approximately true that the pressure of nitrogen gas, when its volume is maintained constant, is proportional to its temperature and that the pressure of this gas diminishes $\frac{1}{273}$ of the pressure which it has at the temperature of melting ice, for every degree centigrade that its temperature is lowered. Hence, if the law continued to hold and the temperature were lowered 273 deg. C. below the temperature of melting ice the gas would have no pressure. The law does not so hold with any actual gas. But Lord Kelvin has shown from thermodynamic considerations that the performance of an ideal gas, in which the law does hold, may be used to assign the lower limit of temperature and to establish an absolute scale of temperature. If a gas has no pressure this means that it is incapable of doing any work, such as raising a piston in a cylinder—or in other words the gas has been robbed of all its energy. When matter has no more energy we speak of it as being absolutely cold and, in a sense, it is dead. The absolute zero of temperature, upon the arbitrary centigrade scale, is, then, 273 deg. C. below the temperature at which ice melts and 373 deg. C. below the temperature at which water boils under the standard pressure of 760 mm of mercury.

The establishment and the increasing of the range of the so-called scale of gas-thermometry has occupied the labors of many physicists of the first rank. The most notable advances in gas-thermometry have been made within the last few years at the Geophysical Laboratory at Washington, D. C., of which Dr. Arthur L. Day is director. In a publication* from this laboratory dated February, 1910, the statement is made that the nitrogen-gas-thermometry scale has been extended by direct observation to the upper limit of 1550 deg. C. with a plus or minus error not exceeding 2 deg. C. Here it must be noted that all extensions of the thermodynamic absolute scale of temperature above this temperature are in the nature of extrapolations. An extrapolation based upon the thermal e.m.f. of a platinum-rhodium thermo-couple has been made up to the melting point of platinum. Other and higher extrapolations are all based upon the assumed truth of two prominent laws of radiation-pyrometry. Extrapolating to the melting point of platinum by the above two methods the agreement is such as to justify an assignment of 1755 deg. C. with a plus or minus error not exceeding 5 deg. C. as the temperature upon the absolute thermo-

dynamic scale at which this metal melts. All that we know of temperatures beyond this is learned solely from the radiant properties of matter.

To fix the scale of temperature up to the melting point of platinum so that this scale may be readily reproduced in any part of the world, physicists have sought for properties of matter which change in a distinct and reproducible way at various points along the temperature scale. Thus for the range of temperature between the freezing and vaporization of mercury, namely 39.5 degs. and 357.2 degs. C. the volume-expansion of this metal in glass or quartz thermometers has proved most convenient. For lower and higher temperatures other properties of matter must be used as reference points. Of all the properties of matter which change with temperature the four which have seemed best to meet the requirements are: the expansion of liquids or solids, the change in the electrical resistance of metals, the thermal e.m.f.s in electric circuits of unlike metals, which have junction points at different temperatures, and the change of state or melting of pure metals and salts which occur sharply at definite temperatures. The most important work of recent years in the fixing of the upper portion of the scale of temperature to the melting point of platinum, has come from the Geophysical Laboratory. The chief object has been to determine very precisely at what temperature, according to the nitrogen-gas-thermometer certain metals and salts, easily obtainable is a state of purity, melt, what e.m.f.s are produced in certain thermo-couple thermometers of standard composition, and how the resistivity of pure platinum varies with the temperature. This work has been largely supplemented, especially in reference to platinum-resistance-thermometry, by the work of the Bureau of Standards at Washington. The fixed temperature points at which standard substances melt and which form a temperature scale by which temperature measuring devices may be calibrated are given in the following list:

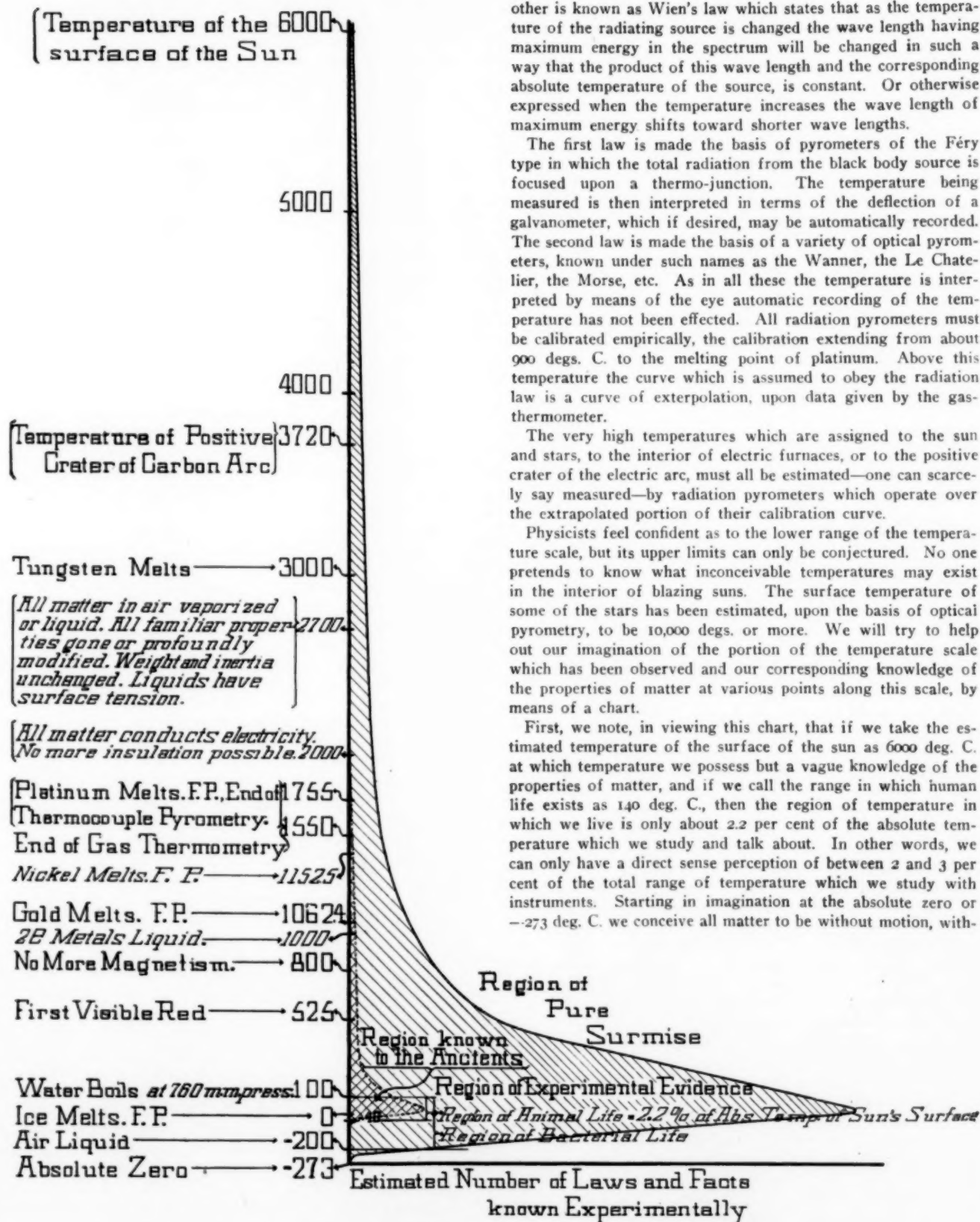
The American Journal of Science, Vol. XXX, July, 1910, page 6.

| | |
|--|---------------------------------|
| Ice, m.p. | 0.0° |
| Water, b.p. | 100.0° + 0.037 (p - 760) |
| Naphthalene, b.p. | 217.7° + 0.057 (p - 760) |
| Benzophenone, b.p. | 305.4° + 0.063 (p - 760) |
| Cadmium, m.p. | 320.2° |
| Zinc, m.p. | 418.2° |
| Antimony, m.p. (in CO) | 630.2° |
| Silver, m.p. (in CO) | 960.0° |
| Gold, m.p. | 1062.4° |
| Copper, m.p. (in CO) | 1082.6° |
| Diopside, m.p. | 1391.2° |
| Nickel, m.p. (in N ₂) | 1452.3° |
| Cobalt, m.p. (in N ₂) | 1489.8° |
| Palladium, m.p. | 1549.2° within $\pm 2^\circ$ C. |
| Platinum, m. p. | 1755.0° within $\pm 5^\circ$ C. |

With these fixed points assigned any thermo-couple of platinum and platinum-rhodium may have its curve of temperature against thermal e.m.f. determined in any part of the world, when it in turn becomes a secondary standard for the measurement of temperature to the melting point of platinum within an accuracy at the upper limit of approximately 5 degs. One has little conception of the long and painstaking investigation which has been required to obtain the above list of fixed temperature points. Dr. A. L. Day remarks (Trans. of the Faraday Society, p. 145, Nov., 1911): "The way is now open for a direct and accurate calibration of radiation pyrometers throughout the region between 900 degs. C. and 1550 degs. C., which should afford a much more certain basis for extrapolation to those extreme temperatures which no laboratory apparatus can withstand."

The methods of optical pyrometry can only be referred to here as the subject is an extensive one. Suffice it to say, that they depend upon two laws of radiation, one known as the Stefan and Boltzmann law, which states that the total energy which is radiated from the bottom of a deep hole in a body

*See also the article by Day, this journal, Vol VIII, p. 257.



RELATION BETWEEN TEMPERATURES AND FACTS KNOWN EXPERIMENTALLY.

made of any substance is proportional to the fourth power of the absolute temperature. In mathematical language $E = K(T - T_0^4)$ where T is the absolute temperature at the bottom of the hole, or so called "black body," and T_0 the absolute temperature of the body on which the radiation falls. The

other is known as Wien's law which states that as the temperature of the radiating source is changed the wave length having maximum energy in the spectrum will be changed in such a way that the product of this wave length and the corresponding absolute temperature of the source, is constant. Or otherwise expressed when the temperature increases the wave length of maximum energy shifts toward shorter wave lengths.

The first law is made the basis of pyrometers of the Féry type in which the total radiation from the black body source is focused upon a thermo-junction. The temperature being measured is then interpreted in terms of the deflection of a galvanometer, which if desired, may be automatically recorded. The second law is made the basis of a variety of optical pyrometers, known under such names as the Wanner, the Le Chatelier, the Morse, etc. As in all these the temperature is interpreted by means of the eye automatic recording of the temperature has not been effected. All radiation pyrometers must be calibrated empirically, the calibration extending from about 900 degs. C. to the melting point of platinum. Above this temperature the curve which is assumed to obey the radiation law is a curve of extrapolation, upon data given by the gas-thermometer.

The very high temperatures which are assigned to the sun and stars, to the interior of electric furnaces, or to the positive crater of the electric arc, must all be estimated—one can scarcely say measured—by radiation pyrometers which operate over the extrapolated portion of their calibration curve.

Physicists feel confident as to the lower range of the temperature scale, but its upper limits can only be conjectured. No one pretends to know what inconceivable temperatures may exist in the interior of blazing suns. The surface temperature of some of the stars has been estimated, upon the basis of optical pyrometry, to be 10,000 degs. or more. We will try to help out our imagination of the portion of the temperature scale which has been observed and our corresponding knowledge of the properties of matter at various points along this scale, by means of a chart.

First, we note, in viewing this chart, that if we take the estimated temperature of the surface of the sun as 6000 deg. C. at which temperature we possess but a vague knowledge of the properties of matter, and if we call the range in which human life exists as 140 deg. C., then the region of temperature in which we live is only about 2.2 per cent of the absolute temperature which we study and talk about. In other words, we can only have a direct sense perception of between 2 and 3 per cent of the total range of temperature which we study with instruments. Starting in imagination at the absolute zero or -273 deg. C. we conceive all matter to be without motion, with-

out energy. It is dead. This final condition has never been observed but where hydrogen is frozen and helium-gas liquid the absolute zero has been reached within 3 or 4 deg. and the condition, and a very few of the properties of several kinds of matter, have been observed.

Here the suggestion is offered, that as metallic conductors have an enormous conductivity, and as the transport of electricity in metals is presumably carried on by mobile negative electrons which obey the laws deduced from the kinetic theory of gases, we have the result that where matter is without energy and dead electricity is active and in motion. It may well be, therefore, that far below the absolute zero for matter there is another zero for electricity where the active electrons themselves become quiescent. While it is pure speculation it is interesting to inquire if there may not exist a cold for electricity in comparison to whom the absolute zero for matter is a white heat.

At -200 deg. C. or 73 deg. abs. air is liquid. If any astronomical cause, or the lapse of time should permanently lower the lowest temperatures which now prevail upon our earth by only some 160 deg. C. the watery fluids of the earth would become plains of hard crystalline rock which much of the now enveloping atmosphere would cover like a soft white snow, for the cold would precipitate it upon a frozen and dead world. We now easily produce this temperature in making liquid air and it is found that many kinds, at least, of the bacteria which are at once man's friends and deadliest foes, still survive. Between -200 deg. C. and -40 deg. C. practically no other life is possible unless it be some low vegetable forms and plant spores. At about -40 deg. C. the higher order of animal life takes its permanent abode upon earth. Antarctic explorers find the emperor penguin living comfortably in large flocks where, as Amundsen recorded, the temperature never rose higher than -5 deg. C. and where it often remains below -40 deg. C.

At 37 deg. C., the blood heat of warm blooded animals, life upon this earth—and I believe throughout the universe—teems. But ascend only 63 deg. C., or a little over 1 per cent of the temperature of the sun's surface, and water boils and all life, including the hardy bacilli, is destroyed. Since the earth as a whole has probably never been colder than it is at present, it is worthy of remark that in the several millions of years that life has been upon its surface the temperature cannot have changed so much as 2 per cent of the temperature of the surface of the sun. It would take but a trifling irregularity in the customary course of the solar system—as the falling of a considerable mass into the sun—to raise the temperature of our earth some 60 deg. C. In this event all protoplasm—the life stuff—would be cooked and two of the three kingdoms on earth, the animal, vegetable, and mineral, would cease to exist.

In the range 100 deg. C. to about 525 deg. C. matter can only be inorganic, and it is not self-luminous. If it is to be seen, it must be illuminated by light from an independent source cast upon it. But Draper has shown that at about a temperature of 525 deg. C. matter of all kinds begins to furnish a faint red glow. The activity of the motion of its particles becomes so great that the ether disturbances produced are able to affect our eyes and as the temperature steadily rises this first faint red glow becomes stronger; orange, yellow, green, blue, indigo and violet rays are successively added with increasing elevation of temperature, until finally the dazzling blue is reached which is found at the temperature of the positive crater of the arc lamp, a temperature which must be attributed some threefold to the surface of the blue stars.

It may be said that below -40 deg. C. matter reveals only faint indications of the life within it which at the absolute zero passes into complete death; that from -40 deg. C. to 100 deg. C. it exhibits an abundant visible life seen in the activity of the protoplasm which it produces, that from 100 deg. C. to 525 deg. C. the life in matter, though not visible to the eye, is to be conjectured from its mass movements and phenomena of contraction and expansion and that above this temperature the life in matter reveals itself with ever increasing visibility until eyes are blinded with the radiant energy which its vibrating particles give rise to.

At about 1000 deg. C. we find at least twenty-seven out of some fifty known metals are molten and flow like mercury. Here

chemical activities are immensely increased, which changes the identity of most all familiar compounds. Our common experience of the chemical properties of bodies and elements avails us little in predicting the chemical reactions which will take place. It thus happens that physicists unfamiliar with high temperature work can make little use of their experience acquired at ordinary temperatures in predicting the nature of the phenomena which, under given conditions, may be expected at this elevated temperature. It is for this reason that even at this moderately high temperature investigation has become a specialty.

At 1550 deg. C. gas-thermometry ends. When the Carnegie Institution at Washington started its investigations the gas-thermometer scale had only been extended, with any pretense at precision, to 1100 deg. C. The recent gain of 450 deg. is largely due to the splendid work of Dr. Arthur L. Day, the director of the Geophysical Laboratory. At 1755 deg. C. platinum, the metal par excellence for measuring temperature, has itself become a liquid. As thermo-couples for high temperature work have always been made of this metal in combination with platinum alloyed with rhodium or iridium, thermo-couples thermometry must end at this temperature unless some heretofore untried metals of still higher melting point be used for the purpose. It is not impossible that molybdenum-tungsten thermo-couples properly protected in an atmosphere of hydrogen might be used under certain circumstances to temperatures up to their exalted melting points.

At 2000 deg. C. almost all substances known to us will be plastic, gaseous or molten. The physical properties of matter at this temperature are but vaguely comprehended. Certainly most familiar properties have gone. All magnetism of matter was left far behind at about 800 deg. C. At this temperature all matter is conducting and there are no more insulators of electricity. If at 2000 deg. C. we are to have electric currents they can only be produced as eddy currents—for no insulators can be found to lead the electric current into directed paths. Ascend another 700° or 800° and all matter, in ordinary atmosphere, will have entered into new chemical combinations, have become liquid or vaporized. It will possess but four or five of the many familiar properties of matter we study and about which we consider we know so much. Hardness, porosity, tensile strength, ductility, elasticity, stability of form, magnetism, color, etc., are all gone. Density, expansibility, thermal and electrical conductivity are profoundly modified. Even the air surrounding such matter has become a conductor due to the thermions which the glowing matter freely emits in abundance.

Two fundamental properties remain, however, constant and unmodified. These two properties are inertia and weight. The kinetic energy of a unit mass of matter moving with a given velocity is just the same at a temperature of 2000 deg. as it is at the temperature of the room, while the earth will attract this matter with the same force whatever its temperature. The surface tension of molten metals persists up to their vaporization point. A portion of molten platinum will form into a liquid globule and roll like quicksilver, and even tungsten which resists before melting almost the highest temperatures we can produce on earth, will gather, when melted, into a bead. This persistence of surface tension strongly suggests that the ultimate particles of matter are attracted toward one another by the same force—gravitation—which draws all bodies—whatever be their temperature—with the one universal law discovered by Newton.

In an atmosphere of hydrogen three at least, and perhaps one or two more metals, recently studied in respect to their melting points, seem to resist fusion up to an elevation of temperature of about 3000 deg. C. Mr. Forsythe of the University of Wisconsin, finds the melting points of tungsten and tantalum to be in the neighborhood of this temperature and when they melt they form a well defined bead in contrast with carbon which has no true melting point, but at about 3700 deg. C. evaporates or sublimates.

Beyond the temperature range of the vaporization of carbon—and we have only reached a little over half way to the estimated temperature of the sun's surface—nothing whatever is known about the properties of matter beyond those which we can infer by studying the radiant energy which it gives off and from observing the manner in which it is acted upon by gravitation.

Our most extensive knowledge respecting the properties of matter is at the habitual temperature in which we live and try most of our laboratory experiments. The past history of physics is, in the main, a recital of the properties, the phenomena, and the laws of matter in the accidental and transitory range of temperature from melting ice to boiling water. If matter at the center of the sun is, as Arrhenius speculates, at the inconceivable temperature of 6,000,000 deg.—being 6000 deg. at its surface and increasing from the surface to the center about 9 deg. C. per kilometer—then the petty range of temperature in which we study matter is but about 1/60,000 of the total range of temperature in which the matter of our solar system exists.

If in our chart we let the height of the straight line represent temperature elevation and if we represent, by distances measured to the right of this line, the number of facts and laws of matter about which we have gathered true experimental evidence, we obtain a curved line which incloses an area that represents, in a conjectural way, the real extent of what we know about matter. Thus, starting at -273 deg. C. or at the absolute zero, we have no experimental facts whatever and the line inclosing our area must begin at the bottom of the line of temperature. With a small rise of temperature our knowledge of the physics of matter increases rapidly. A number of facts are known at the temperature of liquid air but it is at about 20 deg. C., at which temperature most laboratory experiments are tried, that our knowledge is a maximum. It then begins to fall off, slowly at first then very rapidly, until at 2000 deg. C. there are known relatively but very few facts and laws. Above this temperature our knowledge is very slight, being confined chiefly to radiation phenomena and the laws which govern the gravitation of matter.

This area, enclosed between the temperature scale and the limiting line of knowledge, may be called the *Region of Experimental Evidence*. It is the region in which our knowledge of matter rests upon the sure basis of observed facts and carefully made measurements. All outside of this area belongs to the field of imagination and speculation. It may properly be called the *Region of Pure Surmise*. The first region is large compared with that—shown inclosed in dotted line—which the philosophers of antiquity could have drawn to represent the knowledge of their day. But the second, the Region of Pure Surmise, extends beyond all assignable limits.

It is the inheritance and the pride of our generation that we can claim so great an extension from the region of the unknown. By the application of the scientific method, the invention of instruments, and the cooperation of many investigators, the insignificant area which may be assigned to the ancients, in a few generations, has been immensely enlarged. But we cannot rest satisfied, for the craving of intellectual man is to ever explore. Nevertheless, in this exploration we should seek intellectual efficiency quite as much as we strive for commercial efficiency.

To enlarge the region of experimental evidence our explorations should be directed where results will follow in greatest abundance for the efforts put forth—and, we should add, where the knowledge gathered promises to have an immediate or early application to the use and comfort of mankind in general. A glance at the shape of the area of experimental knowledge will show that it needs to be squared up in the temperature-range from 100 deg. C. to 2000 deg. C. Here lies the opportunity of the ambitious investigator to gather precise experimental knowledge of the properties of matter, now totally lacking, at temperatures which we can produce, control, and use industrially.

When the properties of matter are known in this region as they are now known between 0 deg. and 100 deg. C. we may expect industrial uses of the properties of matter of vast and undreamed of service to man.

But the labors of a single individual are brief and very small. Even the well directed and long life of a talented investigator can only put, as it were, a fringe of differential breadth upon the margin of knowledge which is grounded securely upon experiment. But though the extension is slight the intellectual pastime which accompanies the effort is delightful. To accomplish as much as possible in a life time we should give careful heed to plans, methods, and equipment. A canvass of these leads me to believe that it is far more efficient for individuals to examine, study and measure a few important properties of many substances over a considerable range of temperature than to try to do the same for many properties of a few substances. In the former case the same general equipment of apparatus and the experimental experience acquired will be of service, whereas in the latter case many kinds of apparatus, a wider knowledge and a greater expense would be needed to accomplish an equal result.

Of the many properties of matter which deserve investigation, between room temperature and 2000 deg. C., the electrical conduction of matter is a problem which is at once definite and important. As the conduction of matter has interested me, I may be allowed to very briefly consider it here. In the region of temperature at which air is liquid, all bodies are divisible, very sharply, into conductors and insulators. At this temperature the resistivity of all the pure metals is extremely low, the curves all pointing toward zero resistivity at the absolute zero of temperature. The resistivity of the alloys is also low though not so low as that of the pure metals, and the curves do not point toward zero resistivity but above this value at the absolute zero of temperature. The ordinary insulators, on the other hand, are much more perfect insulators at very low temperatures than they are at room temperatures. Ice for example is an excellent insulator long before reaching the temperature of liquid air. The dielectric properties of the insulators, including ice, are extremely good at low temperatures. By good, it is meant that they show very little energy loss per cycle per cubic centimeter per volt when tested with alternating current. It is in fact a safe prediction to state that at the temperature of liquid air all dielectrics, as mica, glass, hard rubber, celluloid, fiber, etc., will not only show an extremely high resistivity but also very little dielectric loss or electric absorption when used in a condenser.

As the temperature rises the so-called insulators diminish in resistivity. Thus Somerville, who has investigated the variation in resistance of glass, porcelain, and quartz, states that these substances begin to decrease in resistance at a very definite temperature and fall rapidly, so that in the small range of temperature from about 500 deg. to 1000 deg. C. the resistance may fall to 1/10 or less of its value at the lower temperature. Also some rods of pottery which measured 10,000,000 ohms at about 550 deg. C. measured only 15,000 ohms at 1100 deg. C. The course of the resistance curve with rise of temperature of an insulator is most familiar in the case of the Nernst glower, which is a good insulator cold and a very good conductor when white hot. The pure metals, and for the most part the alloys, on the other hand, steadily rise in resistivity as the temperature is increased from the lowest attainable to their melting points. At the moment the metals melt they take, as it were, a leap in resistivity. Thus I have found, myself, the ratio of the resistivity after fusion to the resistivity before fusion to be: 1.45 for sodium, 1.52 for potassium, 2.28 for aluminum, roughly 2.5 for copper, 1.98 for cadmium, while investigations, now under way, indicate similar ratios for other metals. Other investigators find the ratio for tin 2.38, for zinc 2.1, for cadmium 2.3 and for lead 1.9. Two German investigators, J. Koenigsberger and K. Schilling, have made a thorough investigation of such half metals as silicon and titanium, and

various oxides and sulphides of the metals. They found in general that the resistivity of these at first decreases, until a minimum is reached, and then continues to increase up to the highest temperature reached in their experiments, which was about 900 degs. C.

It is highly probable that at very high temperatures there ceases to be any distinction whatever between insulators and conductors. Electric conduction is now recognized to be of two kinds: electronic, or conduction by the passage of electrons, in which no chemical decomposition is produced, or counter e.m.f.s. developed, and electrolytic conduction, in which there is chemical decomposition which at room temperatures obeys the law of Faraday. As the temperature is elevated there is good evidence to show that in many substances both kinds of conduction can be taking place at the same time, and it is not known if all conduction may not be electrolytic in all compounds at elevated temperatures, and if so whether or not Faraday's law is obeyed.

Though we may already trace, in general outline, the progress in these modifications in the electrical properties of matter as the temperature is elevated beyond 1000 deg. C. we have little exact data, or anything which deserves the name of precise measurement. The experimental difficulties are great, but great also is the need of precise information. We want it to reduce to a more exact science electric furnace practice and electrometallurgical operations. Quite recently Mr. L. Saunders has made a most commendable effort to determine the temperatures in the interior of a silicon carbide furnace, and has found the decomposition temperature of silicon carbide to be in the neighborhood of 2240 deg. C. But we want this information for, what in my judgment, is a far more important purpose, which is, to give an enlargement to our vision of the cosmos in which we dwell as men and not as mere money accumulating machines. For processes and machines should serve the spirit of man—the last and highest product of evolution—and this spirit must not be sacrificed to its servants.

The goal is to ever extend the region of *experimental evidence* and take a little more from the unlimited region of *pure surmise*. Every one that labors with earnest endeavor and honesty of purpose to improve apparatus, to perfect processes, to build machines, or to study pure science, in laboratory or field, is taking his mite, in the ceaseless conquest, from the region of pure surmise.

Palmer Physical Laboratory,
Princeton, N. J.

Chilean Production of Nitrate.—The production during 1911 exceeded that of any previous year, reaching 54,784,271 quintals (Spanish quintal = 101.41 lb.). The price fell as low as \$1.66 gold per quintal in March, but advanced to \$1.94 in October. New works of a capacity of 18,000,000 per annum were begun last year and will be completed this year. Authority has been granted by the government to put more nitrate land on the market. Nitrate constitutes about 80 per cent of the exports of Chile, and supplies about 60 per cent of the revenue of the government.

Flexibility in wire rope requires relatively small individual wires which do not possess the wearing qualities of ropes having larger outer wires made of higher carbon steel. When such flexible ropes are used on single rope tramways, the spans are limited to 600 ft. in length, with loads of 600 lb. and grades of 1 in 3.

Aerial tramways, if longer than $3\frac{1}{2}$ or 4 miles, are made in sections, shunting the buckets from one to the other. The long cable way in the Argentine Republic, designed to bring ore to Chilecito, is 22 miles long, with a fall of 11,500 ft., and is in eight sections. It carries 40 tons per hour, using buckets of $\frac{1}{2}$ ton capacity.

The Concentration of Carnotite Ores, and Some Similar Ores.

By SIEGFRIED FISCHER.

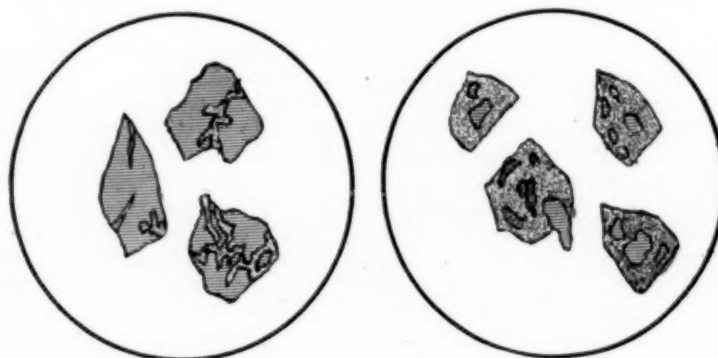
Introduction.

The carnotite ores have recently attracted considerable attention in the commercial world, for the reason that they contain uranium and vanadium salts. It is a well known fact that all the uranium minerals contain a greater or less amount of radium, and it is due to this element that carnotite is such a high priced ore. Its vanadium content has not been given much consideration on account of there being no commercial process at hand for the economical handling of this valuable element in this form. There is, however, a process known abroad, by which the radium is obtained.

Mr. W. F. Bleeker, in his recent articles published in *METALLURGICAL AND CHEMICAL ENGINEERING*,¹ has discussed in detail the present status of the extraction of vanadium from carnotite ores, so that I may omit anything in this line. There has, however, been some recent work done, but I am not at liberty to discuss it.

Carnotite.

Literally speaking, carnotite is a new mineral, and not much is known about it. There are quite a few theories as to its



FIGS. 1 AND 2.—MICROPHOTOGRAPHS OF MEDIUM RICH AND VERY RICH ORES.

chemical composition, but they are not definite. We know, however, that carnotite is a mixture of vanadium and uranium salts; that it usually occurs as an impregnation in some other mineral, such as sandstone, quartzite, coal, etc., and that according to its depth of color, it is richer or poorer in uranium or vanadium.

After having subjected 12 different samples to a minute microscopical examination, the author drew the conclusion that carnotite is a coating on the various mother materials; that each sand grain bears the carnotite as a coating, and that according to the richness of the ore, the coating will be thicker or thinner, more compact or spread. Fig. 1 shows a medium rich ore, and Fig. 2 a very rich one, as they appear under the microscope. The dotted portion represents sandstone, and the ruled areas indicate carnotite. On all the grains we notice some particles of carnotite.

This alone, however, would not be sufficient proof for assuming carnotite to be a coating, and another means had to be sought for to verify the microscopical examination. This was done in the following way: The samples of ore were subjected to grinding under slight pressure. Then by treating this ground material with water the carnotite was removed as suspended slime. By testing each treatment it was found that, on dissolving the particles suspended in the water, and testing the solution so obtained for vanadium, it showed a very strong reaction for this element. On testing the residue left for vanadium it showed only minute traces. The tailings were then dried and again examined under a microscope. The grains of the mother mineral were, practically speaking, free from the

¹Dec., 1910, April and October, 1911.

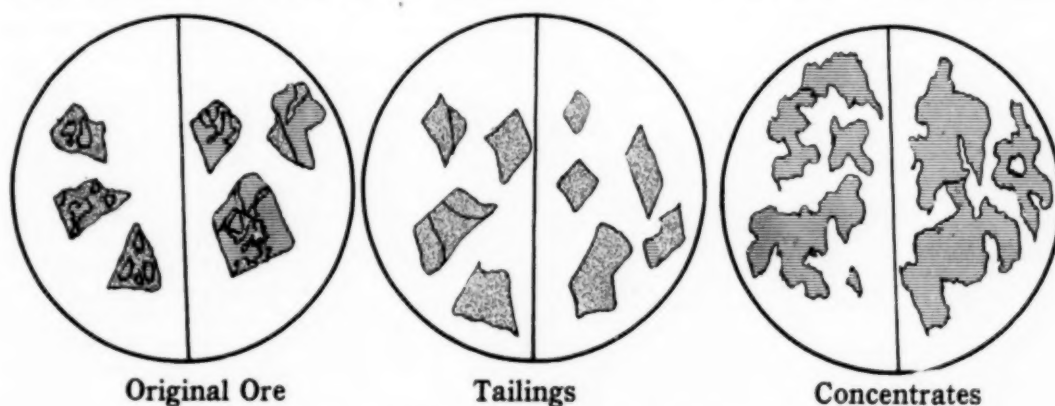
yellow coating. Figs. 3, 4 and 5 show successively the original ore, the concentrated material and the tailing of a medium and a rich carnotite ore. Each ore and its products appear in corresponding halves of the drawings.

Some numerical data will make this clearer: While all of the particles of the original ore showed the carnotite coating, very few of the grains showed a yellow color after grinding. In one case only 3 particles out of 53 in the field of vision showed a slight trace of yellow. In another case, out of 64 particles only 5 showed indications of yellow.

These two tests prove conclusively that carnotite is only a coating or impregnation on the mother mineral, and indicate the fundamental principle upon which the patent for a process for the concentration of carnotite and similar ores is based. This, however, will be discussed later.

Concentration.

At the present time practically all carnotite ore is shipped in its crude form; that is, as it is obtained from the mine. This causes a large and useless expense, in that a large amount of material has to be shipped for which not only no financial return is obtained, but for which freight has to be paid. This



FIGS. 3, 4 AND 5.—RESULTS OF CONCENTRATION.

is the gangue; and if we consider that an ore carrying 4 per cent. vanadium and 5 per cent. uranium is a good commercial ore, we realize what a thorough and economical concentration process means in the carnotite industry.

Treatment: A general outline of the treatment will be in place. After grinding the ore, as much of the carnotite as possible is removed as slime suspended in water. Then the tailings are subjected to grinding and again slimed. This is repeated until the tailings show no reaction for vanadium or only minute traces. In this crude way three treatments are usually sufficient to remove all the carnotite from the gangue mineral. Then the original ore, the concentrates, and the tailings are subjected to a minute microscopical examination, and also tested for vanadium and radium.

The following are some of the results obtained:

Sample No. 1: 200 gms. of ore treated, yielded 127 gms. tailing and 73 gms. concentrate. Equal amounts were used for the vanadium tests and subjected to exactly the same treatment. The concentrate was found to contain practically all the vanadium, while the tailing showed only a trace. The concentration ratio was practically 3:1.

Sample No. 2: Carnotite from the J. Mackay Mine No. 2, Rio Blanco Co., Colo. Same treatment. 61 gms. Original ore yielded 19 gms. concentrate and 42 gms. tailing. The concentrate contained practically all the vanadium, and tailing only a trace. Concentration ratio nearly 3:1.

Sample No. 3: Carnotite from near Greenriver, Utah. Same treatment. 100 gms. original ore yielded 30 gms. concentrate and 70 gms. tailing. The concentrate contained nearly all the vanadium, while tailing showed only a trace. Concentration ratio, 3:1.

These are only a few of the results, but they will make clear the efficiency of the concentration.

The vanadium test is the best criterion for the efficiency of the concentration, for as soon as the tailing shows practically no reaction for vanadium one can be assured that no uranium or radium is left in the tailings. Tests have proved this point.

Another important factor is the mesh to which the ore is ground. The finer the mesh, the more rockslime will the concentrate contain. I will cite two examples:

Fifty gms. of ore that passed through an 80-mesh sieve gave 39.5 gms. concentrate and 10.5 gms. tailing.

Fifty gms. of same ore that passed through a 60-mesh sieve gave: concentrate, 18.5 gms., and tailing, 31.5 gms.

The concentration ratio in the first case is practically 5:4. In the second, nearly 3:1.

The cause of this is, that the carnotite coating is only on the outside of each grain, and not inside. Consequently, if the mesh is finer than the grain the chances for the increase of rockslime in the concentration product are correspondingly greater. It is essential, therefore, in the successful concentration of said ores, to bear this in mind, as it not only enables one to obtain more satisfactory results, but effects also a saving of money and time.

The Principle of the Process of Concentration is as follows: Carnotite being a coating, the principle is in direct connection with this fact. First, remove the coating by abrasion. This may be accomplished by the rubbing against one another of the grains of the

mother mineral, or by machinery, or both. The pressure used to cause the abrasion should be slight, because if too high, the pressure will be sufficient to grind the ore to a finer mesh and so increase the rockslime in the concentrate.

Second, suspend the carnotite in water by slow motion. Draw off water plus the concentrate; collect, and free from as much moisture as possible.

Finally, dry the concentrate by suitable means. The concentrate is then ready for shipment or for further treatment.

Without abrasion it is impossible to concentrate ores of this type. Grinding alone is practically useless as a means of concentration, for the reason already mentioned, namely, the increase of rockslime introduced by too fine grinding. The grinding would have to be exceedingly fine, so fine in fact, that it would hardly pay. But grinding and abrasion combined give the desired results cheaply.

Process: While a combination of various machines will give the same results, the underlying principle for the combination is the same. I will, therefore, simply explain one in detail, the one which accompanies the patent application.

The ore is dumped on a grizzly as it comes from the mine. The finer material drops on a belt-conveyor and goes directly to the ore bin. The coarse material passes through a crusher before being received in the ore bin. From here the ore passes through three sets of rolls. The ground material then enters a Dorr classifier, where the abrasion and suspension of the carnotite take place. The metal shoes which actually are used to convey the tailing out of the classifier, in this case serve also as the desired means of abrasion. The slow motion of the rabblers will give sufficient movement to the solution to suspend the valuable slime. At one end of the classifier the solu-

tion carrying the concentrate enters a Dorr slime thickener, where the slime is settled and freed from part of its moisture. It is then sent to a rotary dryer, and finally to storage bins. If re-treatment is necessary, suitable arrangements are made as shown in diagram.

The process is continuous, and demands little attention and labor. But, as mentioned before, this is only one arrangement

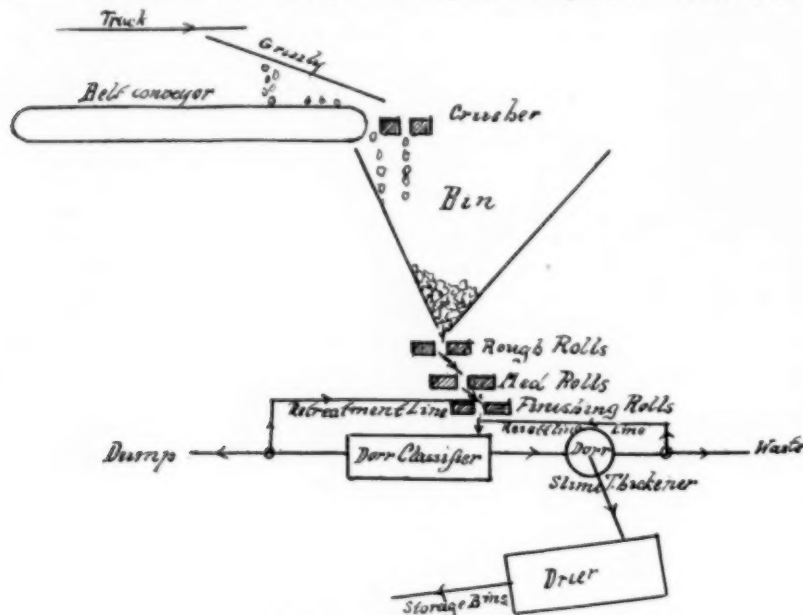


FIG. 6.—DIAGRAM OF PROCESS.

of the many embodying the principle. Fig. 6 gives a diagram of the process.

To make the Dorr classifier work the scrapers will have to have the shape shown in Fig. 7; they must also be adjustable, so that the pressure may be changed by raising or lowering.

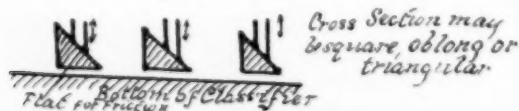


FIG. 7.—SCRAPERS.

The regulation of the pressure for causing the necessary abrasion can be determined in the laboratory while making the tests deciding the mesh.

Mesh Tests: These tests should be made for the different ores, as they give an easy means of obtaining the most desirable results. First notice the structure of the ore, then grind to as near the size of the grain as possible. Then weigh out a definite amount of the sample and put it in a mortar. Wash out all the carnotite possible and rub the remaining material with a pestle; wash again and repeat the operation until the tailing shows no reaction for vanadium, or only a slight trace. Usually three treatments were found to be sufficient. Weigh concentrates and tailing. Until one has obtained a little practice it is best to try 3 or 4 different meshes on the ore. The results should be tabulated, and I would recommend the following scheme:

| NO. OF SAMPLE. | DATE. | |
|---------------------|----------------------|--------------|
| Amount Taken. | Wt. of Conc. | Wt. of Tail. |
| Mesh. | No. of Treat. | Time. |
| PRESSURE: | CONCENTRATION RATIO: | |
| VANADIUM TEST: | SIGNATURE: | |
| MICROSCOPICAL TEST: | | |
| RADIUM TEST: Orig. | | |
| Concent. | | |
| Tail. | | |

Naturally, the tailing and concentrate should be examined

for vanadium and radium, and the results recorded in a similar fashion.

These tests are simple and require very little time. Furthermore, the chemical analysis of the original ore and of the concentrates should be made, but that is self-evident, as that is done in all metallurgical processes.

There is no need of my entering upon the hydrogen peroxide test for vanadium, as it is well known; also the microscopical test, which already has been described.

Radium Test: The best test, to my knowledge, is the test by means of the electrometer. It is comparatively quick and gives fairly accurate results. Precautions must be taken, however, first, that the instrument is free from any radio-active material, and secondly, that small enough amounts are used for the analysis; for it is a well known fact that materials exposed to radium will themselves emanate radio-active rays, and these rays will effect the discharging of the instrument. It is due to this that the above mentioned precautions must be regarded. If small enough amounts are taken this error may be reduced considerably. For emanation does not necessarily mean the presence of the element radium itself; and this latter statement holds true for the tailings.

A test, which in its way is useful, is the exposing of volumetrically equal amounts of the original ore, the concentrates and the tailings to photographic plates, for the same length of time. This is done in the following way:

The plates are first packed in black paper, so that no light can reach them. The amount of each material is measured and put into a small box. On top of the plate a flat metallic object is placed, and this covered by the box containing the material. After exposure the plates are developed and printed. According to the intensity of the picture produced, one may judge as to where most of the radium is to be found. This, of course, is no quantitative determination, but simply serves as a verification to the electrometer in a general way.

Figs. 8, 9, 10, 11, 12 and 13 are photographs obtained in this manner. The exposure lasted for 73.5 hours. The first three show the results obtained from an ore containing approximately 4.5 per cent. uranium. The last three show the results of a very rich ore, of which, unfortunately, I have no quantitative analysis. But, nevertheless, it shows again that the radium is in the concentration product.

All the tests combined prove definitely that all, or practically all, of the valuable mineral is obtained in the process of concentration.

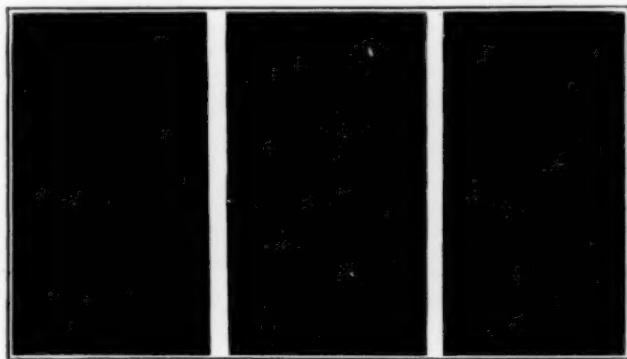
By these tests we also demonstrated that all of the valuable materials are contained in the concentrate, and that the undesirable elements are, if not entirely removed, reduced to a minimum. The concentrate is, therefore, in the best commercial form for shipment, and if a practical process be found for the extraction of the vanadium, the ore could not be in better form. For any chemical process at the present time is handicapped by the large amount of chemicals used for the extraction, due mostly to the fact that the gangue materials consume a large percentage and will give no financial returns.

The concentration will yield over 90 per cent. recovery.

Other materials besides carnotite have been successfully concentrated. Various sandstones carrying only vanadium as a coating have been treated with similar results. The abrasion principle is essential here as with the carnotite. In fact all ores carrying valuable mineral as a coating will bear the same treatment. Some ores naturally will have to undergo more than one treatment, but the cheapness of the process makes this only a very small factor.

The Value of the Process.

In considering the commercial side of the process, I will use the data obtained from a firm shipping a carnotite ore worth \$200 a ton. We will also use the minimum values for the cost and freight. The same ore was concentrated by the above

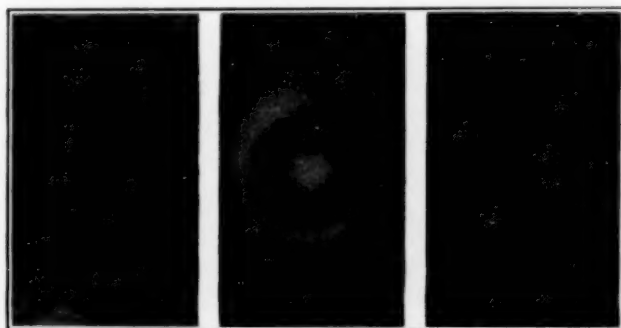


FIGS. 8, 9, 10. PHOTOGRAPHS SHOWING THE CONCENTRATION OF RADIUM CONTENTS IN UTAH CARNOTITE.

process, and not having any definite figures we will assume the maximum cost for its production.

| | |
|--|-----------|
| Value per ton of original ore..... | \$200.00 |
| Cost of production per ton..... | .20 |
| Freight per ton (to Europe)..... | 20.00 |
| Actual value per ton..... | 179.80 |
| Value per ton of concentrate (ratio 3:1).... | 600.00 |
| Cost of production per ton (maximum)..... | 10.00 |
| Freight (to Europe)..... | 25.00 |
| Actual value per ton..... | 565.00 |
| 100 tons @ \$179.80 (original)..... | 17,980.00 |
| 100 tons @ \$565 (concentrate)..... | 56,500.00 |

The gain, without any doubt, is noticeable and even should



FIGS. 11, 12, 13. PHOTOGRAPHS SHOWING CONCENTRATION OF RADIUM CONTENTS IN RICH CARNOTITE ORE (COLORADO).

the cost of production exceed the figures given, which is not likely, the profit is still enormous.

Golden, Colo.

The Upward Concentration of Kish by Flotation.

By HENRY M. HOWE.

In an extremely interesting and valuable article Dr. Paul Goerens¹ informs us that the so-called primary graphite "is distributed very evenly (*durchaus gleichmässig verteilt ist*)" in a remarkable specimen of cast iron made and cooled slowly in the electric furnace, and containing about 7.5 per cent of carbon, of which about 6.5 per cent existed as graphite. The prominent facts are (1) that much of this graphite existed in ex-

tremely large flakes; (2) that he calls these "primary graphite"; (3) that he indicates that they form at the liquidus BD; and (4) that his diagram Fig. 1 suggests that kish is identical with primary graphite. From these facts one might well believe that these great flakes are identical in origin with kish.

But one immediately asks how it is possible that true kish should be distributed evenly throughout the interior of a mass of cast iron. The solidification of such a mass of cast iron, of

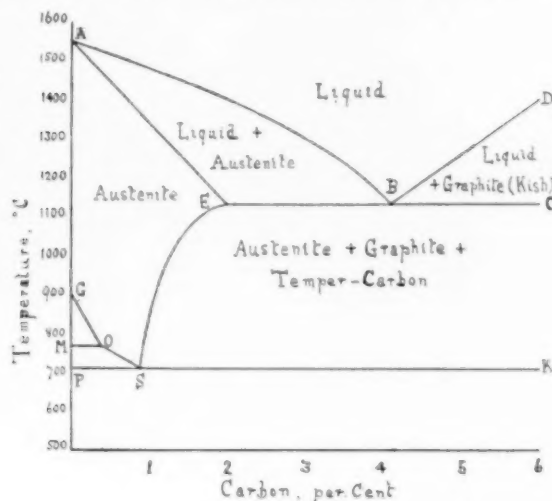
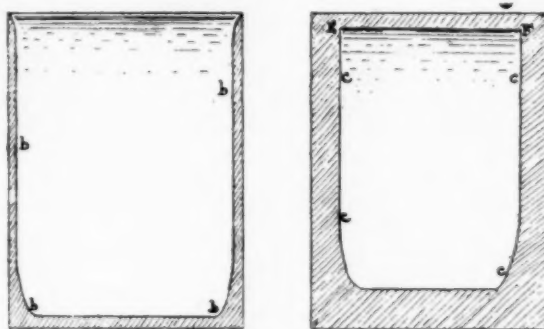


FIG. 1. CARBON-IRON DIAGRAM (GOERENS).

course, takes place progressively from without inward as sketched in Figs. 2 and 3. It is perfectly familiar to us that, while some kinds of cast iron are molten as in Fig. 2, flakes of kish do escape from the upper surface, which would appear to indicate that they have risen to that upper surface from some lower position, either from the molten iron, or, as is more probable, from that submerged layer *bbbb* which at the moment is solidifying, and is therefore at the shore line between the already solidified part and the still molten interior. To be more exact, we should naturally suppose that this throwing off of kish occurs in those layers which at the moment are either at the liquidus itself or between the liquidus and the eutectic freezing point.

If this natural conception of the origin of kish is true, then it is very hard to understand why there should not be a concen-



FIGS. 2 AND 3. CONJECTURED COURSE OF SOLIDIFICATION OF A CAST IRON INGOT.

tration of kish in the upper part of the mass. We should naturally suppose that the course of events which led the solidifying layers *bbbb* in Fig. 2 to expel kish which rises to the surface and escapes into the air before the upper surface crusts over, would also continue at the shore layer *cccc*, Fig. 3, after that upper surface has crusted over. And if they did so continue, then it would be inevitable that those flakes which have risen and would have escaped if the upper surface had remained

¹Metallurgie, 1907, 4, p. 137.

molten, must be caught and concentrated in the upper part of the casting at the line *EF* by the crust which has now formed across the upper surface.

Moreover, this condition of affairs ought to continue as the upper surface grows thicker and thicker. As the crust which forms on the top of the molten mass gradually thickens by the

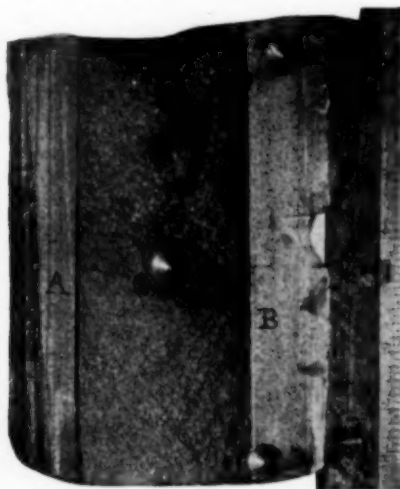


FIG. 4. INGOT OF KISH-BEARING CAST IRON IN WHICH THE UPWARD CONCENTRATION OF KISH WAS FOUND.

solidification of fresh layers on its lower side, each layer as it solidifies should catch some of the upward-rising kish, and in that way should become enriched in graphite at the expense of the layers *cccc*, which are below the molten part.

A very valuable paper by Mr. J. E. Johnson, Jr.,² indicated that there is such concentration of kish in the upper part of castings made directly from the blast furnace. Mr. Johnson says, "Whereas, if the metal is allowed to cool to some extent before pouring, graphite begins to form within it, and separates out at eddies and high points of the mold, with objectionable results."

Mr. T. D. West informs me that in his practice in making ingot molds with cast iron direct from the blast furnace, bottom cast, and thereby probably nearly freed from mechanically entrained kish, about half a peck (say, 270 cu. in.) of kish would rise to the top of 3-ton casting and have to be scraped off. Indeed, he found it necessary to have the molds open at the top in order that he might be able thus to remove the kish from the top of the casting.³

It is true that in none of these cases does attention seem to have been directed to the special point before us, whether within the solid metal the large flakes assumed to represent kish are distributed evenly. From the fact that in Mr. West's case this rising of kish seems clearly to have continued after the solidification of part of the iron had begun, we infer that it is extremely probable that kish evolved still later would be caught in the upper part of the casting. But to change a probability into a certainty I asked Mr. Edward B. Cook, manager of the Warwick Iron & Steel Company, Pottstown, Pa., to make for me a casting from pig-iron running from one of his furnaces at a time when that furnace was making kish-bearing iron. To that end I sent him a steel mold 6 in. in diameter and 8 in. high, consisting of a piece of common steel tubing closed at the bottom with a steel cap.

This casting when broken open did not show clearly to the naked eye any marks of upward concentration of graphite, although there was a sharp line of demarkation running across it as shown at *AB* in Fig. 4. But chemical analyses of borings taken at the points 1, 2 and 3 showed that there was a very great upward concentration. There is about 1.1 per cent more

graphite at the top than near the bottom. The graphite content as determined by Messrs. Booth, Garrett, and Blair was as follows:

| | Graphitic carbon. |
|-----------------------|-------------------|
| 1. "Top" | 3.700 per cent. |
| | 3.682 per cent. |
| 2. "Below pipe" | 2.748 per cent. |
| 3. "Bottom" | 2.596 per cent. |
| | 2.582 per cent. |

Flotation or Segregation.

If this concentration of graphite in the upper part of the casting simply represented the common course of segregation, by which the most fusible matter concentrates in the last freezing part, then the enrichment ought to be most marked in that last freezing part, which, as experience indicates, is usually just below the bottom of the pipe. But if that concentration represents in large part the entanglement of upward swimming kish expelled from the submerged solidifying layers, *bbbb* or *cccc*, then the enrichment in graphite ought to be greater at the top of the ingot than at the bottom of the pipe, and this we find to be the case.

We see that there is, as might be expected, a slight enrichment in graphite just below the pipe, but it is very slight. On the other hand, there is an enormous enrichment at the top of the ingot. This is not the last solidifying part, and therefore the enrichment here must necessarily represent the flotation of kish and its entanglement in the solidifying upper layers, as distinguished from the progressive concentration in the last freezing region by normal segregation.

From Ruff's analysis⁴ of his experiments I believe that this kish is not primary graphite, but the product of the graphitization of cementite. The most natural supposition is that this cementite is primary. It is very probable that these graphite flakes are not pseudomorphs after primary cementite, because their strong curvature is so very unlike the usual striking blade-straightness of primary cementite crystals. They certainly seem to be idiomorphic. Their idiomorphism contains a strong suggestion that they have formed direct from the molten, or in other words that each particle of carbon between the instant when it precipitates in the form of primary cementite and the almost immediately following instant when it had graphitized and joined the particles of graphite which had previously assembled, has redissolved in the molten metal and re-precipitated from it, forming an idiomorphic crystal with these previously assembled particles. It is true that the time available is extremely brief; yet it may suffice. Thus we know that, whereas in Ruff's relatively rapid coolings in which he quenched molten cast iron in iced water, the graphitization of the cementite went very far; yet in Hanemann's experiments⁵ which differed from Ruff's chiefly in having a still faster rate of solidification, the cementite often escaped graphitization and apparently nearly completely, and was retained in very large part in the form of crystals of primary and eutectic cementite, often of extraordinary beauty. That Hanemann's rapidity of cooling was in fact much greater than Ruff's is seen not only from his thus retaining the cementite ungraphitized, but from an inspection of his conditions. Ruff's molten iron was thrown into the water while still remaining in its crucible, and therefore was exposed to the cooling water only on its upper surface, and even this would necessarily be protected from the water by the envelope of ill-conducting vapor which surrounds a metal quenched in almost any liquid. Hanemann poured his molten metal into a narrow metal mould, so that there was direct contact between molten metal and solid metal, with excellent opportunity for rapid transfer of heat from the small quantity of molten metal to the large mass of the cold and rapidly conducting mould.

Columbia University, New York City.

²Trans. American Inst. Mining Engineers, 1905, Vol. 35, pp. 212-223.

³Private communication, April 4, 1912.

⁴Metallurgie, 8, p. 462, Aug. 8, 1911.

⁵Stahl und Eisen, 37, p. 333, March 2, 1911.

Dry Cells—Their Uses and Testing

THREE years ago (December, 1909, vol. VII, p. 501), we made the following remarks: "The dry cell industry in this country has now an annual output of some 40,000,000 cells and is still continually growing. But the general lack of exact knowledge about the dry cell is appalling, while the usual methods of rating dry cells reminds one at best of kindergarten methods for making electricity easy." These remarks were made on the occasion of the appointment of a Committee on Dry Cell Tests by the American Electrochemical Society and we expressed the hope that through the work of this committee the deplorable situation would be effectively changed.

This committee presented at the recent Boston meeting of the American Electrochemical Society a preliminary report, which, while only tentative, deserves fullest publicity so as to bring out intelligent discussion.

Tentative Report of American Electrochemical Society Committee on Dry Cell Tests

The committee consisted of Prof. C. F. BURGESS, chairman, and Dr. J. W. BROWN, Mr. F. H. LOVERIDGE, and Dr. C. H. SHARP.

The report divides dry cell tests into three main groups: (1) tests to determine whether or not a cell is in good condition before being placed in service; (2) tests to determine the actual or comparative service capacity of cells, and (3) tests to determine the rate of deterioration of cells on open circuit.

(1.) Tests to Determine the Condition of a Cell Before Use

*I. Electromotive Force.*¹—The electromotive force of a cell may be read by connecting a voltmeter directly across the terminals. In new cells of various types the electromotive force may vary from 1.5 to 1.6 volts. If a cell of the type now in general use gives an e.m.f. five or more hundredths less than 1.5 volts it is an almost certain indication either of serious deterioration due to age, or of the external short-circuiting of the cell, or of some defect such as an internal short-circuit, which will soon render the cell unfit for service.

It is seldom necessary to measure the open-circuit voltage of cells, since they are seldom deficient in this respect. It is a test which may be considered as secondary in nature, and should be applied when it is suspected that the cells are below standard, for example, when cells are received with wet jackets, when the terminals are corroded, when the electrolyte leaks from under the seal, or when the cells are abnormally low in short-circuit current.

An accurate or carefully calibrated voltmeter should be used, the resistance of which is sufficiently high to render the current flow through it inappreciable. A two-scale Weston instrument of 300 ohms resistance with 3-volt maximum deflection and 1500 ohms with 15 volts maximum deflection has been found very satisfactory for both cells and batteries. Cheap pocket instruments are often so inaccurate as to make their indications of open circuit voltage worse than useless.

The effect of temperature on electromotive force is very slight, amounting to only a few hundredths of a volt between all ordinary temperature ranges. The voltage returns to normal with the temperature.

II. Short-circuit Current.—The short-circuit current of a cell may be obtained by connecting an ammeter directly across the terminals of the cell.

The short-circuit current of a cell is of value only when

coupled with a familiarity with the brand of cell in question. If the reading is normal for that brand of cell, it is reasonably certain that the particular cell is in good condition, and that it will probably give as good service as others of the same make. This applies only to cells of the same brand and make. That the short-circuit current of a cell of a new and unfamiliar brand is as high as that of another brand is no indication whatever of the equality of the service capacities of the two cells.² The short-circuit current bears no relationship to service, and when measured without reference to temperature or other conditions may be entirely meaningless and misleading.

The ammeter for reading short-circuit current should be dead-beat, and with its leads should have a resistance of 0.01 ohm, to within 0.002 ohm. Two 30-inch lengths of No. 12 lamp-cord make very convenient leads. The maximum swing of the needle should be taken as the short-circuit current of the cell.

The ammeter should be connected across the brass terminals of the electrodes. Low readings are apt to be obtained if the ammeter is applied to the carbon electrode directly.

In order to avoid high contact resistance, the terminals of the cells and of the ammeter leads should be brightened. It has been found very convenient to fit the ammeter leads with small terminals of lead. The contact on the cell terminals is greatly improved, and with such leads it is unnecessary to brighten the contacts.

For accurate measurement of the short-circuit current of a new cell, cheap instruments of the pocket type should be avoided.³

The effect of temperature on the short-circuit current⁴ is quite pronounced. Between 10 and 80 degrees centigrade, the amperage of cells is raised on an average of about 1 ampere for each 10 degrees centigrade rise in temperature. This value varies considerably with different cells, and is somewhat greater at the lower (colder) end of the scale and less at the higher. At very low temperatures the effect is very pronounced, and it is often noted that cells received in extremely cold weather read but one or two amperes. On bringing them to room temperature, however, the short-circuit current becomes normal and the cell is not impaired by the freezing.

*III. Internal Resistance.*⁵—This value is usually determined by applying the formula:

$$\text{Int. Res.} = \frac{V - V'}{C}$$

where V is the open circuit voltage of the cell, V' the closed circuit voltage, and C the current drain to which the cell is subjected in order to make the determination.

The above formula gives a compound value, composed partly of the sum of the resistances of the various parts of the cell, and partly of the resultant of the various electromotive forces in operation during the action of the cell. The value obtained varies with the current flowing, the age of the cell, and the temperature. For these reasons the committee advises against the use of this test. It indicates nothing in regard to the service capacity, nor does it give an exact value of the actual internal resistance of the cell.

(2.) Service Capacity Tests—General Discussion

Requirements for a satisfactory test.—In general there are but two reasons for desiring a service test upon dry cells:

¹Trans. Amer. Electrochem. Soc., vol. 13, p. 178 (1908); vol. 16, p. 110 (1909); vol. 17, p. 346 (1910); vol. 19, p. 33 (1911).

²Trans. Amer. Electrochem. Soc., vol. 16, p. 117 (1909).

³Trans. Amer. Electrochem. Soc., vol. 17, p. 356 (1910); vol. 19, p. 37 (1911).

⁴Trans. Amer. Electrochem. Soc., vol. 17, p. 348 (1910).

⁵Trans. Amer. Electrochem. Soc., vol. 16, p. 103 (1909); vol. 17, p. 345 (1910).

1. To ascertain what life may be obtained from a brand of cells in a certain service.

2. To ascertain which one of several brands will give the longest life in that particular service.

With the former object in view the knowledge is best obtained by actual use of the cells in connection with the appliance. In some cases this is the only feasible way in which the definite information sought can be obtained. The great majority of tests are carried on, however, with the second object in view, viz., the comparison of two or more brands of cells for use in a particular service. Where the amount of testing is large, it is impossible, even were it expedient, to use the actual appliances for testing cells, and it becomes necessary to devise special testing methods and apparatus such that results obtained therefrom shall be comparable to the results obtained from the cells when placed in actual service. This is the one necessary condition which dry cell tests must fulfil.

There have been tests devised which seek to go further and make the operating conditions not only comparable, but as similar as may be to the operating conditions of the service for which the test is intended. Upon this point there is some diversity of opinion. Some authorities claim that a test is of greater value and is more reliable the more nearly the conditions of test approach those of service, and, following out these claims, have devised certain tests which are rendered quite complicated, requiring much attention and apparatus for their continuance, by the introduction into the method of some of the irregularities to be expected in service. It is questionable, however, if results of greater meaning are obtained from such strict adherence to service conditions. At best, such a test is but an approach to actual service, which must be continually varying from time to time and from locality to locality. Again, the apparatus necessary to carry on an irregular, intermittent test is very complicated and requires much careful attention. This feature limits its use to the large consumers and manufacturers.

Testing cells in series.—It has been suggested that cells of various makes be tested by connecting them in series and discharging them simultaneously through any suitable resistance, thereby assuring that the cells are discharged at the same rate and under identical conditions. There are several objections to this method* and the committee therefore advises against the testing of cells in this manner.

Judging Results.—In interpreting the results obtained from a test of various grades of cells, the committee cautions against drawing definite conclusions from the outcome of a single test or of a small number of tests. When the matter of choosing a brand is of much importance, it is necessary to run a series of tests over a period of six months or a year. In this way a very good idea may be obtained of the average service results which may be expected.

In the following table are given the results of ten monthly tests completed during 1910 on two brands of dry cells. The values represent the length of service given:

| Tests. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Ave. |
|--------------|----|----|----|----|----|----|----|----|----|----|------|
| Brand A..... | 42 | 35 | 38 | 33 | 60 | 45 | 48 | 35 | 66 | 48 | 45.0 |
| Brand B..... | 30 | 37 | 24 | 25 | 27 | 40 | 48 | 42 | 40 | 40 | 35.3 |

It is very evident from a comparison of the averages of these tests that Brand A is much superior to Brand B, yet had the consumer only the results from tests 2 or 8, he would have undoubtedly arrived at a very erroneous conclusion regarding the real merits of the two brands.

Service Tests Recommended

I. Telephone Service: Discharge three cells, connected in series, through 20 ohms resistance for a period of two minutes, each hour, during 24 hours per day and seven days per week,

*Trans. Amer. Electrochem. Soc., vol. 19, p. 36 (1911).

*Trans. Amer. Electrochem. Soc., vol. 17, p. 358 (1910); vol. 19, p. 41 (1911).

until the closed circuit voltage of the battery at the end of a period of contact falls to 2.8 volts.

The following readings are taken:

1. Initial open circuit voltage of the battery.
2. Initial closed circuit voltage of the battery.
3. Closed circuit voltage at the end of the first discharged period.
4. Closed circuit voltage at the end of a discharged period after three days, and weekly thereafter.

Report the results as the number of days during which the closed circuit voltage remains above the limiting value of 2.8 volts.

Notes.—Fig. 1 shows in diagrammatic form a very convenient and inexpensive method of carrying on this test.

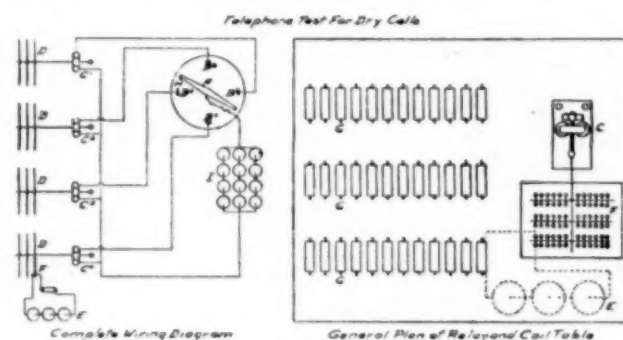


FIG. 1. DRY CELL TEST FOR TELEPHONE SERVICE.

The left hand portion indicates the apparatus necessary and its arrangement. The hand of the clock *A* revolves once per hour, closing, by means of a suitable contact *H*, the circuit of the battery *I* in turn through the contacts *B*₁, *B*₂, *B*₃ and *B*₄, on the face of the clock. This current magnetizes in turn the cores of the relays *C*₁, *C*₂, *C*₃ and *C*₄, causing the extended armature arms *D* to fall, bringing the inverted U shaped fingers *F* into mercury cups, to which the terminals of the individual test circuits are connected. Each contact plate *B* is of such length that two minutes are required for the passage of the contact *H*.

At the right of the figure is shown one testing unit, consisting of the relay *C*, the mercury cups into which dip the contact fingers *F*, and the arrangement of the 20-ohm resistance coils *G*.

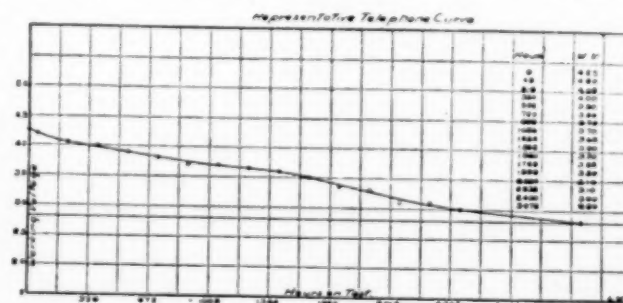


FIG. 2. REPRESENTATIVE DRY CELL DISCHARGE CURVE FOR TELEPHONE SERVICE TEST.

The batteries *E*, are stored under the table on which the various parts are fixed. One complete test battery circuit is indicated by the dotted lines.

Fig. 2 shows a representative discharge curve obtained from a battery of three 2½ x 6 inch (6 x 15 cm.) cells of a well known brand. The curve passes through the values of the closed circuit voltage at the ends of the contact periods.

The test should be conducted in a dry place, and normal room temperature should be maintained as closely as possible.

II. Ignition Service: Discharge six cells connected in series through 16 ohms resistance for two periods of one hour each

per day, seven days per week. The periods should be eleven hours apart, but in cases where the circuits are not automatically controlled, the first and the last hour in the working day may be chosen for the discharge periods and the discharge omitted on Sunday, without materially affecting the results.

The following readings are taken:

1. The initial open circuit voltage and short-circuit current of the battery.

2. The initial closed circuit or working voltage, and the initial impulse of current which the battery is capable of forcing through a 0.5-ohm coil connected in series with an ammeter, and in parallel with the 16-ohm coil.

3. Closed circuit voltage and impulse current through the 0.5-ohm coil at the end of the first period of closure, at the end of the sixth period, at the end of the twelfth period and after every twelfth period thereafter.

The test is considered completed when the impulse current at the end of a period falls below four amperes. Report the results as the number of hours of actual discharge to the limiting value of impulse current.

Fig. 3 shows diagrammatically the arrangement for a single test.

When the number of tests is not large the circuits may easily be closed by hand. When a great many tests are to be made,

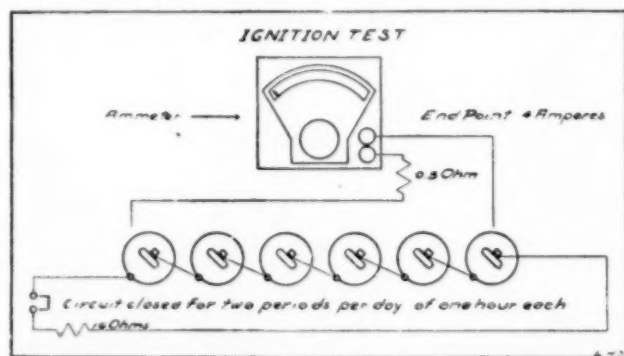


FIG. 3. DRY CELL TEST FOR IGNITION SERVICE.

it is convenient to arrange a clock-operated automatic circuit closing device.

By varying the length or number of discharge periods, the test may be made representative of any special cases of ignition. For a good comparison of the fitness of various cells for general ignition service, however, the test as given above is to be recommended.

Particular care should be taken to keep the temperature of ignition test batteries as nearly constant as possible, as the service obtainable is greatly influenced by this factor, as shown by the following table, in which are given the averages of five separate tests conducted at 5, 25, 35, 45, 55, 65 and 75 degrees centigrade.

| | | | | | | | |
|--------------------|------|------|------|------|------|------|------|
| Temperature | 5° | 25° | 35° | 45° | 55° | 65° | 75° |
| Hours service..... | 31.9 | 46.3 | 50.4 | 46.2 | 35.6 | 29.3 | 26.6 |

The reasons for the adoption of the various constants of this test, viz., number of cells, resistance in main circuit, end point, and resistance in ammeter circuit, is fully described in the Trans. Amer. Electrochem. Soc., vol. 13, p. 178 (1908); vol. 17, p. 361 (1910); vol. 19, p. 43 (1911).

III. Flash-light Batteries: Discharge the battery to be tested through a resistance of four ohms for every cell in series, viz., eight ohms for a two-cell battery and 12 ohms for a three-cell battery, for a period of five minutes once each day until the closed circuit voltage at the end of a discharge period falls to 0.75 volt per cell, viz., 1.5 volts for a two-cell and 2.25 volts for a three-cell battery.

The following readings are taken:

1. Initial open-circuit voltage and short-circuit current.

2. Initial closed-circuit, or working voltage.

3. Closed-circuit voltage at the end of the first, third and seventh periods of closure, and after each seventh period thereafter.

Report the results as the number of minutes during which the battery was discharged through the resistance to the given end point.

In case the circuits are not operated mechanically, the results are not materially changed if the batteries are discharged only on working days.

Four ohms per cell is chosen for the resistance in circuit, since the tungsten bulbs generally used with a three-cell battery have a resistance of approximately 12 ohms.

Miscellaneous Services: In addition to the telephone and ignition services, which are by far the most important services in which dry cells are used, there are numerous other services, among which may be mentioned the operation of automobile horns, sewing machine motors, small fans, toys, massage vibrators, cigar lighters, bells, buzzers, etc. In the aggregate these miscellaneous services consume enormous numbers of cells, but they are so numerous, and there are such variable conditions prevailing in each kind of service, that it would be useless to attempt to develop standard tests covering them.

It is not difficult for anyone particularly interested in any special service to arrange a suitable test for himself. Care should be taken to make the conditions of test, viz., number of cells, resistance in circuit, period of drain, etc., approximate those of the service in question.

(3.) Rate of Deterioration on Open Circuit

The voltage and short-circuit current of the cells for test are read initially in order to insure that the cells are in good condition. The cells are then stored in a dry place of normal room temperature.

The following readings are taken:

1. Initial voltage and short-circuit current.

2. Short-circuit current at the end of four weeks, eight weeks and each eight weeks thereafter.

3. Voltage at the end of six months.

The cells are kept on the shelf until the short-circuit current has fallen below 10 amperes. This point is arbitrarily chosen, as it represents a point below which it would be difficult to market the cell. For practical purposes, the results are expressed as the number of months during which the short-circuit current remains above this cut-off point. Much more meaning, however, is attached to the rate at which the current falls, generally reported as the drop in amperage for a given period expressed as a percentage of the initial amperage. This is especially true when investigation of the quality of cells is the object. For practical purposes, however, the first rating given, i. e., months to 10 amperes, is perhaps preferable.

The results from this test are largely indicative of increase in internal resistance, and bear no definite relation to the service which the cells may give. However, this information, coupled with familiarity with a brand of cells, becomes a very good indication of its quality. It also serves to indicate any serious defects of manufacture.

The ammeter for reading short-circuit current should be dead-beat, and with its leads should have a resistance of 0.01 ohm. Two 30-inch lengths of No. 12 lamp cord make very convenient leads.

Particular attention should be given to the temperature at which cells are stored, as the rate of deterioration is influenced to a marked degree by the temperature of the cells.⁸

The ideal method for an open-circuit deterioration test would be the determination of the decrease of service capacity due to storage over definite periods. This practice, however, would entail much labor and expense when the amount of testing to be done is large.

⁸Trans. Amer. Electrochem. Soc., vol. 17, p. 357 (1910); vol. 19, p. 39 (1911).

Finally the committee discusses the *adaptability of these tests to the needs of the various classes of consumers.*

First the *small users*, the number of which is legion, cannot conduct any kind of service test. The only safe course for him is to purchase a reputable brand of cell and perhaps to read the short-circuit current of every cell purchased thereafter to see whether the reading is normal and the cell in good condition.

The class of "*small dealer*" comprises those dealers who may dispose of from a few hundred to a thousand or more cells per year. The dealer is particularly interested in keeping the quality of his stock up to the standard. As cells are received, a representative sample, e. g., 10 per cent. chosen at random throughout the lot, should be read with a reliable make of ammeter. If the readings are normal it would scarcely profit to make further tests. For his protection all cells should be read with the ammeter before being delivered to customers.

The *jobber* buys and sells dry cells largely by barrel lots, and in many cases conducts no tests whatever. If he is desirous of keeping his quality strictly up to standard it would be well to open several barrels in each shipment and test with an ammeter a dozen cells chosen at random throughout the barrel. If the large jobber wishes to carry the best grade of cell for any service, it would probably pay him to conduct the recommended telephone and ignition tests on a small scale. The consumer, however, has more interest in the service to be obtained from cells than has the jobber, but, as noted above, the small average number purchased by the consumer prohibits tests of any magnitude. Therefore if the jobber takes up dry cell testing seriously, it would be with the ultimate aim of protecting and building up the reputation of the small consumer.

The *small telephone company*, consuming say less than ten barrels of cells per year, could install a standard telephone test of small capacity by fitting suitable electrical contacts on a clock and connecting these with a telegraph relay in such a way as to cause the latter to open and close the dry-cell circuits. The Committee advises that such a test be maintained by each company and that periodical tests (at least four per year) be made on the shipment of cells received and also on small lots of other brands purchased from time to time for the purpose of test. The small company should also test a representative sample (say 10 per cent.) of all consignments received, with a good ammeter.

The *large telephone company*, using many barrels of cells per year, can well afford to install an apparatus for carrying on the test suggested in this report. The Committee advises that a battery of three cells from each consignment received be placed upon the telephone test. It, however, considers two such tests per month as a safe maximum number of tests. In addition the short-circuit current and open-circuit voltage should be read upon a representative sample of all cells received. It would be profitable for the large telephone company to conduct regular telephone tests, not only upon the batteries used with their equipment, but also batteries composed of the different makes of cells, in order to compare their relative merits on telephone service.

To the *gas engine manufacturer* it is important that the batteries furnished with his engine be the best cells obtainable from an ignition standpoint. As the apparatus necessary for carrying on the ignition test is quite inexpensive, and as the test requires very little attention, the manufacturer of such engines purchasing a considerable number of cells should conduct the ignition test not only as a check upon the cells he is receiving, but as a basis for judging the merits of the different grades of ignition cells which are available at that time on the market.

An ignition test upon six cells from every fifth barrel received with a maximum of two tests for a single consignment of cells, would probably be sufficient. Before being sent out

with an engine the short-circuit current on all cells should be read and those reading abnormally low (e. g., 5 amperes or more below the average for the brand and grade) should be rejected.

Short-Circuit Current and Deterioration of Dry Cells

At the Boston meeting of the Electrochemical Society another interesting paper on dry cell performance was presented by Mr. CARL HAMBUECHEN, of the Northern Chemical Engineering Laboratories of Madison, Wis.

Mr. Hambuechen, who has made since 1908 several thousand dry-cell tests on all kinds of commercial brands, points out that there are three important characteristics of dry cells by which merit is judged, these being commonly designated as the "flash" or "short-circuit current," the "shelf life" and the watt-hour output or "service capacity." The first is of the least importance and the last is the most important, as determining the actual merits of the product, but as to the frequency of use, this order is reversed, and it is by the flash test that the largest proportion of dry cells sold are judged.

Now because the short-circuit current test is in such universal use (the average user choosing that cell which gives the highest short-circuit current), the dry-cell manufacturer is naturally subject to the temptation to turn out a product giving a high short-circuit current, regardless of other probably far more desirable properties.

Mr. Hambuechen's observations make it certain that there has been a tendency in recent years to construct dry cells so

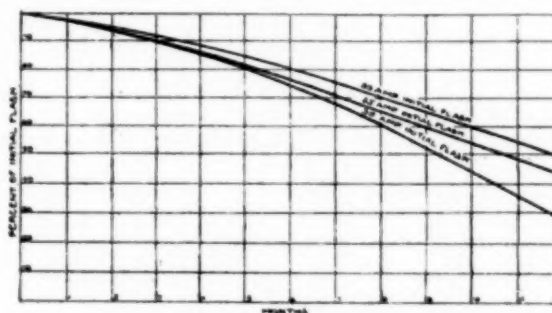


FIG. 4. NORMAL DETERIORATION CURVES.

as to give a higher and higher short-circuit current. In 1899 the flash test or initial amperage of commercial American dry cells varied between two and ten amperes. There has been a gradual upward tendency since that time, and this upper tendency is still continuing. Since 1908 the initial amperage of the ignition-type cell has been raised from 20 to over 30 amperes, while with the telephone-type cell the amperage has been raised from 15 to nearly 30 amperes. There are various methods by which the initial amperage may be increased, including the use of graphite and higher conductive carbon, the increase in the percentage of this material with a corresponding decrease in the manganese and other constituents, by the use of various chemicals which increase the activity, by the use of thinner and more porous lining for the cells, and by the density and hardness of tamp, etc.

The question naturally presents itself as to whether in the attainment of a high flash some of the other desirable characteristics may not be sacrificed, and from the author's observation it appears that during the past three years there has been little, if any, improvement in the cell durability or shelf-wear or in the watt-hour capacity; in fact, there is some evidence that these important qualities have been sacrificed in the attainment of high amperage.

Interesting in this connection, as well as interesting in itself, is the question: "What is the rate of normal shelf-deterioration for a standard well-made cell under normal temperature conditions?"

This question is answered in Mr. Hambuechen's curves of Fig. 4, which show the normal deterioration of the more prominent types of cells on the market during the past year.

It is noteworthy that cells made with higher initial amperage show a more rapid deterioration than those giving initially a lower flash test as indicated by the three curves for cells having initially 20, 25 and 30 amperes respectively. It has been pointed out by Messrs. Pritz and Ordway that the falling off in flash tests does not by any means indicate a corresponding reduction in useful service capacity, and the author confirms these observations. Nevertheless, it is desirable that cells be improved for shelf wear, and the above curves indicate that marked opportunity for improvement exists.

British Comparative Dry Cell Tests

Finally an abstract will be given of a recent Faraday Society paper of Mr. S. W. MELSON, of the (British) National Physical Laboratory, entitled "Dry batteries; the relation between the incidence of the discharge and the relative capacity of cells of different manufacture."

Owing to the absence of agreement as to the method of testing likely to give the best comparative results, it was felt desirable, before settling on a definite test for use in the National Physical Laboratory, to make a comparison between results obtained with a number of the tests in general use and those obtained by a test, the conditions of which approximated as nearly as possible to actual working conditions. The cells subjected to the various tests were selected not in order to ascertain which type of cell is the best when taken into practical use, but with a view to determining the most suitable method of testing dry cells. The four types chosen for the purpose of the investigation were, therefore, those which previous tests had indicated as widely different.

The size of cell employed was that most generally used for telephone work in England, the dimensions over all being 7 in. by 2½ in. by 2½ in. Sixty cells of the requisite size of each of the four types were supplied by the manufacturers, and four cells of each make were selected at random for each of the discharges mentioned. It was evident from the close agreement between the individual cells in each group that this number could be taken as fairly representative of the type. The four makes of cells are designated as A, B, C and D respectively.

The following series of seven tests were taken as being representative of those in general use:

Test 1 (discharge for 5 minutes per hour through a resistance of 50 ohms per cell) represents as nearly as possible the working conditions of a cell on a telephone circuit. The information on which this test is based was supplied by the National Telephone Co., i. e., two cells working on a circuit, the resistance of which is about 100 ohms and the average discharge five minutes per hour. Measurements were made by the National Telephone Co., and it was found that the minimum current with which a telephone microphone would work was 0.018 ampere, and the discharge of the cells was, therefore, considered to be completed when the voltage had fallen to 0.9 volt at the end of any period of discharge.

Test 2 was a discharge for five minutes per hour through a resistance of 1 ohm.

Test 3 was specified by the National Telephone Co., the cells in this case being discharged continuously for six hours per day through a resistance of 5 ohms, resting the other 18 hours. The discharge in this case was considered to be complete when the voltage of each cell, taken after the period of rest, had fallen to 0.9 volt, when discharged for two minutes through a resistance of 50 ohms.

Test 4 was the test formerly specified by the British Post Office. Each cell was discharged continuously at a constant current (in this case 20 milliamperes) until the e. m. f. observed immediately after the current was switched off, had fallen to one volt.

Test 5 is the test most favored by British manufacturers, each cell being discharged continuously through a resistance of 10 ohms. This test is largely used, but the various users are seldom agreed as to the point at which the discharge should be considered complete. Three complete discharges were made under these conditions; one immediately after the cells were received, one after six months' storage, and another after the cells had been stored for 12 months.

In test 6 each cell was discharged through a resistance of 100 ohms, the discharge being considered to be complete when the voltage had fallen to 0.9 volt per cell.

Test 7 is one of the tests used by the (British) War Office, and consists in observing the voltage of the cell when it is discharged continuously through a resistance of 500 ohms.

Results of the Tests.—The volt-hours, ampere-hours and watt-hours given by each cell (the result in each case being the mean of four cells), and, in addition, the relative value of each set of cells, taking for this purpose the output of cells

TABLE I.—Relative Capacity of the Cells at Various Rates of Discharge (The values are in watt-hours, except where otherwise stated.)

| No. | | CELLS. | | | |
|-----|---|--------|-----|----|----|
| | | A. | B. | C. | D. |
| 1 | 5 mins. an hour on 50 ohms..... | 100 | 93 | 83 | 28 |
| | 5 mins. an hour on 1 ohm. Initial..... | 100 | 59 | 43 | 7 |
| 2 | After 6 months' storage..... | 100 | 58 | 50 | — |
| | After 12 months' storage..... | 100 | 53 | 42 | — |
| 3 | 6 hours per day on 5 ohms— | | | | |
| | Mean of V.B. and V.E. curves..... | 100 | 50 | 50 | 35 |
| | Continuous at 20 milliamperes— | | | | |
| | Initial ampere-hours..... | 100 | 43 | 36 | 30 |
| 4 | Initial watt-hours..... | 100 | 45 | 40 | 29 |
| | After 8 months' storage, watt-hours..... | 100 | 50 | 45 | 5 |
| | Continuous on 10 ohms— | | | | |
| | Initial to 0.7 volt..... | 100 | 75 | 53 | 60 |
| 5 | Initial to 0.5 volt..... | 100 | 76 | 55 | 60 |
| | After 6 months' storage, to 0.7 volt..... | 100 | 59 | 44 | 28 |
| | After 12 months' storage..... | 100 | 67 | 50 | 2 |
| 6 | Continuous on 100 ohms..... | 100 | 68 | 51 | 35 |
| | Continuous on 500 ohms— | | | | |
| 7 | To 1.3 volt..... | 100 | 102 | 87 | 10 |
| | To end, i. e., 118 weeks..... | 100 | 94 | — | — |

TABLE II.—Relation between Incidence of Discharge and Capacity. (The capacity in each case is given in watt-hours.)

| Test No. | CELLS. | | | |
|----------|--------|----|----|----|
| | A. | B. | C. | D. |
| 1 | 43 | 40 | 36 | 12 |
| 2 | 44 | 26 | 19 | 3 |
| 3 | 126 | 63 | 63 | 46 |
| 4 | 105 | 47 | 42 | 31 |
| 5 | 64 | 49 | 35 | 38 |
| 6 | 107 | 73 | 55 | 38 |
| 7 | 70 | 66 | — | — |

A as 100, are given in the paper in form of curves. A summary of the relative values is given in Table I, which is herewith reproduced. It will be seen that the order of merit was the same throughout, but the relative capacity varied considerably. The reason for this is apparently due to different methods of manufacture.

Capacity at Various Rates of Discharge.—In order to determine accurately the capacity of dry cells at various rates of discharge, it would be necessary to fix upon a point at which the discharge should be considered to be complete, at each of the various rates. This point should, of course, be based upon the relation of the fall in voltage to the current which is drawn from the cells. In the present work the limit was, in most cases, that specified by the various users of cells. Therefore the summary of results, given in Table II, must be taken only as an approximation.

The differences are, however, in some cases so large that the effect of stopping the discharge at a slightly higher or lower point on the curve would not seriously affect them. For the purpose of comparison we might dismiss cells D, that type

being so different from the others, especially in its keeping properties. On the intermittent discharge (No. 1) all the cells gave a lower capacity than when discharged continuously at about the same current; this result is remarkable, inasmuch as the cells A, B and C, tested by the continuous discharges, showed little or no deterioration after 12 months' storage.

Conclusions.—In view of the great difference between the relative results of different makes of cells under the various conditions of discharge, and also as to the relation between the incidence of the discharge and the capacity, it seems obvious that, with the exception of No. 1, none of the methods of test investigated can be relied on to give even an approximation of the relative capacity of dry cells or of the output which may be obtained under working conditions. What may be called a "rough idea" of the relative value might, perhaps, be obtained for telephonic purposes from the results of a continuous discharge through a resistance of 100 ohms, but for a really correct comparison the test should approximate as nearly as possible to working conditions.

The author has not made a large number of tests on the larger types of dry cell, such as are used for ignition purposes, but from the results obtained with those that have been tested there seems every reason to believe that the conclusions arrived at as a result of this investigation would apply also to them; the rate of discharge being, of course, in proportion to the size of the cell.

A standard test of this sort, although it would of necessity take a considerable time and might at first sight be considered laborious, would eventually show distinctly which brand of cell is the best suited to the requirements, and would give a very fair approximation of the cost of the energy used. Moreover, satisfactory mechanical arrangements can readily be made for switching the cells off and on, and it is only necessary then to take readings of the voltage about once a week, at, or near, the end of a discharge period. The observations of voltage on open circuit and of internal resistance—at best somewhat indefinite, and always difficult to interpret—would not be required; the process of recording observations would, therefore, be much simplified.

Condensers and Condensation for Vacuum Plants.

BY B. VIOLA, M. E.,

Member American Society of Mechanical Engineers.

The condensation of vapors may be carried out in two different ways, viz., by dry surface-condensation or by wet injection-condensation, according to whether the vapor comes in contact with the cooling water only indirectly by means of a dry cooling surface or directly without intervening plates.

Dry condensation is commonly employed in steam engine plants in order to keep the feed water free from impurities or salts; wet condensation is generally used where cold water (seldom cold air) may be directly injected into the condenser without disadvantage.

Another distinction is made between direct-current and counter-current condensers, according to whether the cooling water and the steam or vapor move in the same or in opposite directions. In either case the steam or vapor is deprived of the latent heat by which it was produced, and it is precipitated once more as water in the form of drops, while simultaneously the pressure exerted by the steam disappears and a vacuum is produced.

Wet condensation is the kind chiefly used in vacuum plants. The cooling surface here is the surface of the cooling liquid while flowing off. The steam, being brought into contact with this cooling surface, will condense, reducing its volume and pressure. According to the ability of the cooling water to consume heat, a certain quantity of steam can be condensed continuously per unit of time and surface.

If a vacuum pan is connected with a condenser, the reduction of pressure in the condenser will communicate itself to the

steam space, in consequence of the tendency toward equalization of pressures in communicating rooms, and the difference of pressure between boiling surface and condensation surface will be only the amount of pressure required for overcoming the resistance of friction of steam and gases during their motion. These resistances are very different, according to the construction of the condensers and the shape and dimensions of the connecting pipes.

In order to maintain a constant pressure in the vacuum pan, it is not merely sufficient to condense the vapors. With the cooling water a vast amount of atmospheric air and carbonic acid is introduced continuously into the apparatus. Besides, the alkaline earths dissolved in the water can produce gases which will become noticeable at higher temperatures. Even in the evaporator gases, carbonic acid, etc., are produced. All the gases set free from the cooling water have a motion opposite

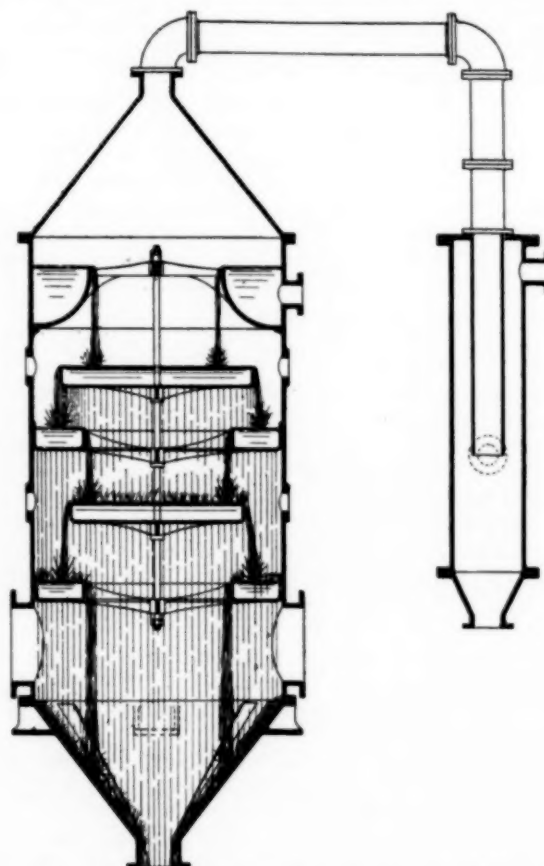


FIG. 71.—CROSS-SECTION OF COUNTER-CURRENT CONDENSER.

to that of the steam; they penetrate the latter, mix with the gases coming from the evaporator and alter their own motion only in the upper part of the condenser, or at the air-pump connection.

If the gases were not allowed to escape from the condenser they would soon fill the room of the vacuum pan to such an extent that in spite of good condensation the pressure would be considerably increased. They would also follow the pitch to the cooling surface, taking up the volume formerly occupied by the condensed steam, would delay the cooling of the steam, and finally stop condensation altogether. To avoid this, an air pump is attached to the upper part of every counter-current condenser in order to take care of these gases.

The cooling water gives off the absorbed air upon entering the condenser in the same proportion as the pressure is reduced. The air is, therefore, carried off by the air pump from the upper part of the condenser at the lowest temperature, never reaching the lower part of the condenser and only promoting the condensation of the vapors in the upper part.

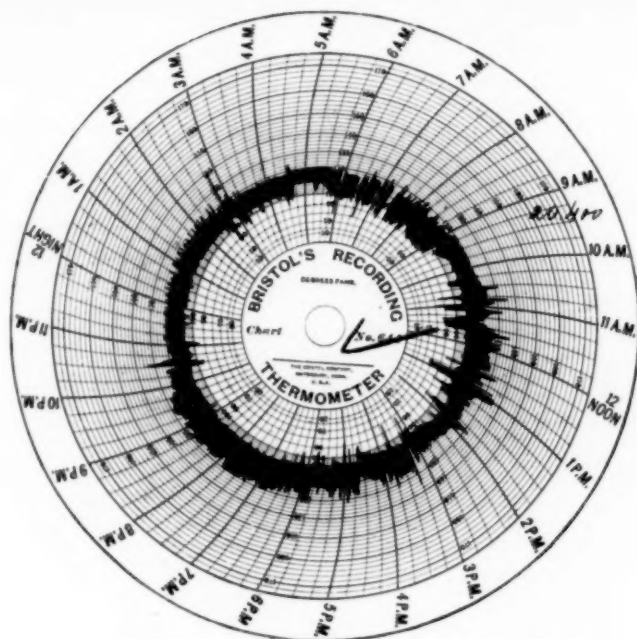


FIG. 73.—TEMPERATURE CHART OF CONDENSE WATER WITH AUTOMATIC REGULATION.

It is generally known that 0.07 is the proportion of air in the water in a wet condenser, including that passing through leaky joints.

We therefore see how important it is never to inject any more water than the vapors require for their condensation.

In practice it is very often found that by an incorrect working of the vacuum, or of the condensing plant, the injection of cooling water is increased. Such a faulty operation is indicated by various symptoms, but most strikingly by the temperature of the condensed water. If the flow of cooling water is too rapid the work of the air pump is immediately made more difficult, since a great deal more air is to be removed. If the air pump is accurately proportioned according to the size of the plant, it will now be unable to accomplish the work. If it is larger, the work is done at the expense of more steam. If a wet-air pump is employed it is called upon to remove more air and water. Moreover, the excessive injection of water will cause a higher pressure in the condenser.

Suppose the falling water to be a liquid cylinder, the outer surface or mantle of this cylinder will, upon entering into the hot steam, first take up the heat of the steam, while the interior parts remain cooler. If, owing to the great velocity of fall, the interior portions of the water column are unable to effect cooling as well as the exterior surface, the discharged water will be heated only to a moderate degree. But if an equalization of temperature can be brought about through the whole cylinder of water, while it is falling, the cooling power of the water is utilized to much better effect.

The finer the water can be subdivided in falling the more readily will the gases pass through it, and their resistance will be diminished as the surface increases.

The subdivision of the water brings about largely the escape of the air from the cooling water. But the division never is fine enough, hence in counter-current condensers the real counter-flow takes place only upon the surface where the water and steam are in contact. But the utilization of the cooling surface also depends on the time of contact; that is, on the time for which there is a maximum temperature difference between water and steam.

For the free fall of a body of water the time of falling t is equal to the velocity v , divided by the gravity g , or $t = v/g$. The height of the fall h expressed by the velocity is found from

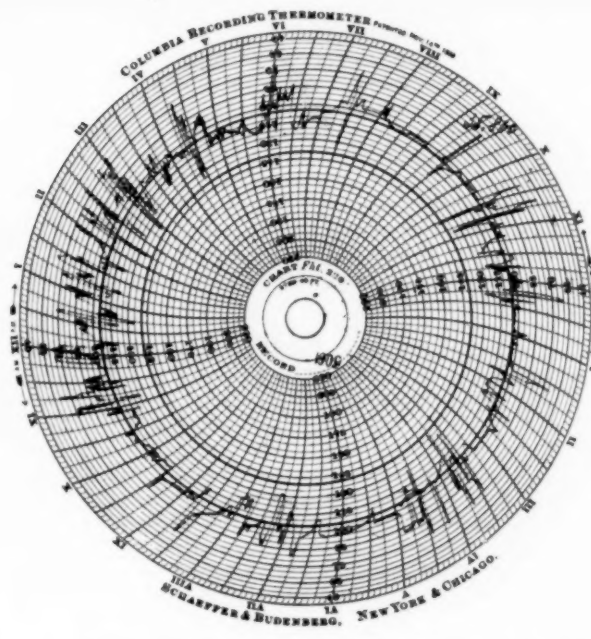


FIG. 72.—TEMPERATURE CHART OF CONDENSE WATER WITH HAND REGULATION.

$$v = \sqrt{2gh} \text{ or } t_h = \frac{\sqrt{2gh}}{g} = \sqrt{\frac{2}{g}} \times \sqrt{h}$$

Applying this equation to condensation, we may say that the time t_h required for a fall from the height h increases proportionately to the square root of the height of the fall. But with the height of fall, the resistance in the condenser also increases.

We can divide the height of fall into n parts (for instance, by providing a series of basins or trays as will be described later on) and thus have:

$$h = n \times h/n.$$

The partial fall being h/n , and giving to the resistances the smallest value possible, and to the time of transferring heat in the condenser the highest value, we call the limit of the time of contact of water and heat $t_{(nh/n)}$ and have this equation:

$$t_{(nh/n)} = \sqrt{2nh/n/g}.$$

From this we derive the proportion:

$$\frac{t_h}{t_{(nh/n)}} = \frac{1}{\sqrt{n}}.$$

Then for every value of $n > 1$ we shall also have

$$t_{(nh/n)} > t_h, \text{ and in general } t_{(nh/n)} = \sqrt{n} t_h.$$

If we make n very large and h/n very small, we shall proportionately extend the time of contact between steam and water in the condenser.

$$\frac{h}{n} = \frac{gt^2}{2n^2}$$

It is necessary, however, that the partial fall h/n be not less than the value required by the amount of steam to be condensed.

From this calculation we see that the velocity of the water is governed by the height of fall and it is advisable to restrict this height in order to prevent friction resistance, if for no other reason. The smallest value of friction resistance corresponds to $h = 0$, that is, the condition when steam and gases flow over standing water. Plants of such construction, however, would be too large. Moreover, water and gases being poor heat conductors when in a state of rest, it is necessary to provide for a certain degree of motion for the water in a condenser.

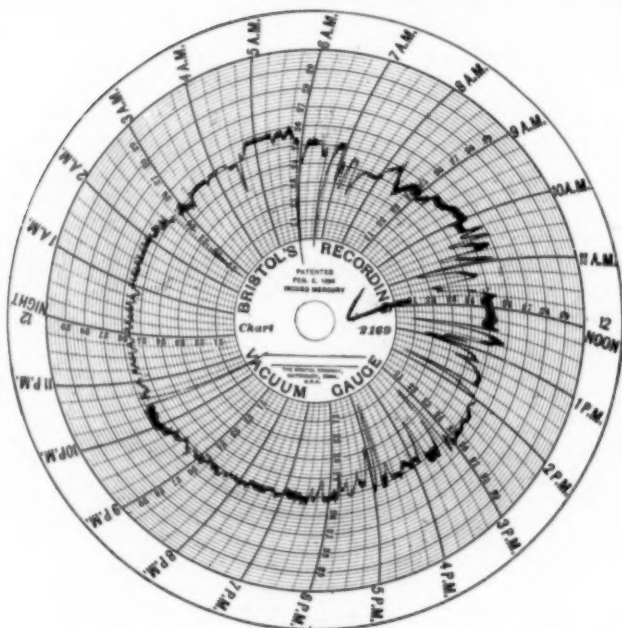


FIG. 74.—VACUUM CHART SHOWING CHANGES OF VACUUM DURING CHARGING OF TANKS.

Further, the quantity of steam condensed per unit of time is directly proportional to the cooling surface and a division of the cooling water is therefore equivalent to an extension of the cooling surface.

Therefore, to heat the condenser water quickly to the necessary temperature by direct contact with steam, it is necessary,

1. That the surface of the cooling water be large;
2. That the cooling surface change quickly, and

3. That the time of contact between steam and water be as long as possible.

To fulfill these conditions, a concentric counter-current condenser such as that shown in Fig. 71 gives the best results. This condenser is designed for use in connection with two or more vacuum pans. By the addition of basins or trays the duration of the contact between water and steam is raised in the ratio of \sqrt{n} , resulting in an economy of water. Some water will accumulate in each of these trays temporarily and the temperature is, therefore, equalized at each stage. The fresh supply of water will sink to the bottom of the tray, forcing the lower stratum upward on account of the difference in temperature, and the warmer water will flow over from one tray to the next. The trays in this manner form zones with the desired small difference of temperature and constitute a graduated scale of temperatures from the temperature of the steam admission to that of the gas outlet.

The surface of condensation depends primarily on the size of the cooling-water cylinder when the depth of the trays is greater than zero. It may even be said that these moving water columns promote the cooling, and air and gases will pass at the surface of the trays even though they do not pass at the bottom. During the time the water remains in the trays it has a chance to take up more heat which is withdrawn from the steam. It is very important that enough water be permitted to flow to secure good results, but by providing the trays with spray holes the cooling effect of the water is considerably increased.

The work of the condenser varies with temperature, but in general it performs about 610 times the work of the air pump, volumetrically speaking. It is absolutely necessary to exhaust the air and gases to promote condensation, but the best air pump cannot do good work with a poor condenser, while a good condenser accomplishes at least fair results with an indifferent air pump.

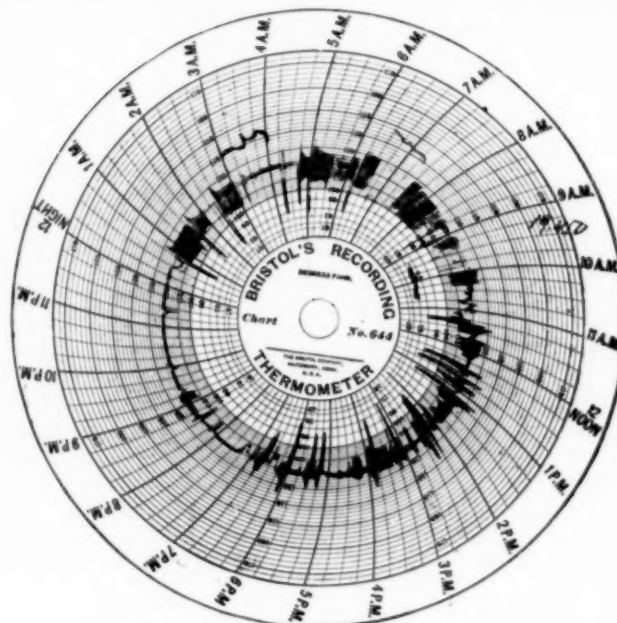


FIG. 75.—TEMPERATURE CHART OF CONDENSE WATER WITH AUTOMATIC REGULATION.

As I have explained, it is very important that the correct quantity of water be used to condense a certain quantity of steam. This matter is neglected in most condensing plants and some kind of automatic device should be applied to regulate the flow of cooling water. Experience has shown that the amount of water should be from 20 to 40 times that of the steam to be condensed. This permits variations within very wide limits and in large condensing plants where immense quantities of cooling water are required some controlling device should be applied for economical reasons to prevent waste of water.

The first step is to decide at what temperature the water should be discharged from the condenser. This, of course, bears a certain relation to the steam to be condensed.

A record of experiments made and of results achieved with a condensing plant used in connection with vacuum pans, by the author, will now be given. I first applied a recording thermometer in the tail pipe of a concentric barometric condenser for the purpose of controlling the cooling water by hand operation of the inlet valve; but it was very difficult to convince the operator of the condenser that it was not necessary to let the cooling water run off cold, because it is generally believed the colder the water the higher the vacuum.

The variations of temperature with hand control can be seen in Fig. 72. After experimenting some time it was found very difficult to secure good results by hand regulation, because of the continuous changes which must be made to meet conditions as the number of pans connected to the condenser is increased or decreased. This led to the application of an automatic temperature controller in the tail pipe connected to the compressed-air inlet valve, and by this means it was found possible to feed the condenser approximately in proportion to the steam or vapor which had to be condensed. As a result the average temperature of the condense water was improved and the variations were reduced so as to be only slight.

The temperature of the condense water at a given time may be compared with the corresponding vacuum secured by automatic regulation. (Figs. 73 and 74.) By maintaining the temperature of the condense water nearly equal a very uniform vacuum was obtained except at periods when a new vacuum pan was charged.

The most striking changes will be noticed at 10:30 p. m.,

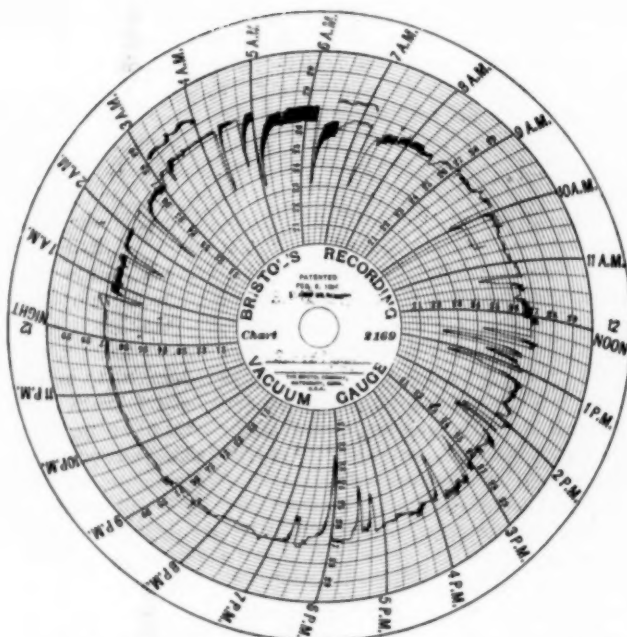


FIG. 76.—CHART SHOWING HIGH VACUUM WITH CONTROLLED COOLING WATER.

2:45, and 6:00 a. m. in Fig. 74. At the same periods the controlling thermometer showed a considerable fall in temperature, due solely to the temperature of the air drawn in from a newly charged pan which was filled with air at the temperature of the operating room. The vacuum pump draws it into the condenser and as a consequence of this the vacuum drops until all the air is drawn out and the new pan reaches an equilibrium with the vacuum which the pump is able to keep up in connection with the other pans.

During this period of low vacuum the water is shut off by the controlling valve so that no cooling water whatever enters the condenser. Since the other pans are boiling, the temperature in the condenser increases until the water left in the trays is raised to the temperature limit, when the controlling valve opens and the cooling water is again admitted.

The fact that the higher vacuum is not obtained with an excess of cooling water can be seen from Figs. 73 and 74. Between 4:45 and 5:15 a. m., when according to the chart the lowest temperature was 110 deg. F. and the highest 120 deg. F., the corresponding vacuum was 25.8 inches. The charts shown in Figs. 75 and 76 show even higher vacuums with a temperature of 120 deg. F., the same vacuum pump and the same number of vacuum pans being used in each case.

On all the charts, especially on the temperature charts, most of the records are made up from lines going up and down from the lowest to the highest limit of temperatures, but these lines are so near to each other that it seems to be a continuous surface. The formation of these surfaces can be noticed on the vacuum chart No. 77. These variations are caused by the working of the controlling thermometer, which is always set to a certain highest temperature at which the condense water has to be discharged. After reaching that temperature the combination of the construction causes the opening of the water valve and as soon as the temperature falls, the feed valve gets closed partly so that the water inlet will be considerably diminished.

Doherty Patents on Gas Producer Operation Upheld in the Final Court.

The United States Circuit Court of Appeals for the First Circuit has handed down a decision sustaining the earlier decision of the United States Circuit Court for the district of

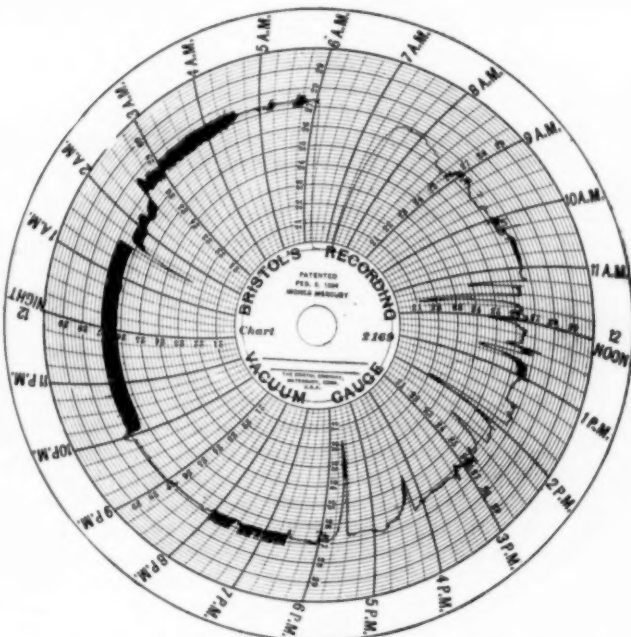


FIG. 77.—VACUUM CHART SHOWING DETAILS OF FLUCTUATIONS OF VACUUM.

Massachusetts in the case of the Combustion Utilities Corporation vs. the Worcester Gas Light Company.

The question at issue in both courts was the validity of the patents of Henry L. Doherty covering a means of controlling and regulating the temperature in gas producers. The defendant in the original suit claimed that Doherty's inventions were anticipated in the prior art and were therefore invalid. The trial of the case was held before Judge Brown in the United States Circuit Court of Massachusetts. The Doherty patents cover both an apparatus and a process, embracing the use of a part of the products of combustion in such a way as to restrain the temperature in the incandescent fuel bed in the producer below the point at which the ash can fuse or flux into a clinker. The result is a producer free from the troubles and expense attendant upon clinker in the furnace.

The original suit grew out of the installation of some gas benches for the Worcester Gas Light Company by a prominent builder, which were claimed to infringe the Doherty patents. Because of the importance of the questions at issue, the case commanded widespread attention. Judge Brown, in his decision, stated that "a very protracted and careful examination of the record convinces me that Doherty made a meritorious advance in the art; that he was the inventor both of an apparatus and a new process."

The Court of Appeals—the three justices unanimously concurring—sustains the decision of the lower court completely, making no exceptions whatever. And as this is the court of last resort the patents of Mr. Doherty are fully sustained.

A New Slime Density Table.

By H. B. LOWDEN

Slime density tables heretofore published have been prepared for use in special cases and are, therefore, not applicable to slimes in which the specific gravity of the solids differs from that for which the table was computed. Their value has been chiefly in indicating convenient forms in which the weight and volume relations may be tabulated for use in the control of the cyanide process. The writer, having experienced the need of a more generally applicable table in his work, has prepared one of considerable range with small intervals, which he feels may be useful to others.

The table is based on the percentage of solid in the slime,

opposite which is given the ratio of solid to liquid. The numbers heading the double columns following, are the specific gravities of the dry solid (that of water being taken as unity). The columns headed S. G. show the specific gravities of the slime, that of water being taken as 1000; that is, the figures show directly the weight of a liter of slime in grams. The columns headed Vol. show the number of cubic feet of the slime in one ton of 2000 pounds.

The specific gravities of solids chosen will probably cover the range of slimes ordinarily met with and the intervals are sufficiently small to admit of interpolation without appreciable error. The last column (4.50) is a hypothetical concentrate and is the specific gravity of a mixture of 80 per cent pyrite and 20 per cent quartz. The average specific gravity of working cyanide solutions is so small as to be negligible.

The table is convenient for ascertaining the amount of solid and of solution in slime pulps from the number of cubic feet, determined by rod or float, in the tank; and specific gravity of the slime, determined by taking the weight of a liter or by a specific gravity indicator in the tank. It is useful in calculations for ascertaining the amount of solution to be abstracted or added in thickening and diluting, for correcting the strength

of the solutions, for checking tonnage and for other purposes.

Assume that in a plant in which the specific gravity of the solid is 2.7, a tank is shown, by the depth of pulp in it, to contain 3530 cubic feet of pulp, a liter of which weighs 1223 grams. From the table it is found that the specific gravity 1223 corresponds to 26.16 cubic feet per ton and to 29 per cent solid. The weight of pulp, therefore, is $3530 \div 26.16 = 135$ tons and the weight of solids $135 \times 0.29 = 39.15$ tons. The weight of solution is, by difference, 95.85 tons. If the solution titrates 1.05 pounds cyanide per ton and it is desired to bring the strength up to 2.5 pounds per ton, we have $2.5 - 1.05 = 1.45$ pounds cyanide to be added per ton. Therefore $95.85 \times 1.45 = 139$ pounds cyanide to be added to the tank.

The table is useful in determining the sizes of tanks necessary for any given capacities. Thus, if it is desired to agitate 50 tons of dry slime (specific gravity of solid 2.6) with three parts solution, the table shows this to contain 25 per cent solids and to have a volume of 27.08 cubic feet per ton: therefore $50 \div 0.25 = 200$ tons of slime $\times 27.08 = 5416$ cubic feet, the required effective working capacity of the tank, to which an amount must be added to secure the desired height of curb above the charge.

SLIME DENSITY RELATIONS.

| Per Cent Solids. | Ratio of Solids to Solution. | Specific Gravity of Pulp and Volume of One Ton in Cubic Feet, for Slimes Containing Solids of Different Specific Gravities. | | | | | | | | | |
|------------------|------------------------------|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | | 2.50 | | 2.60 | | 2.70 | | 2.80 | | 2.90 | |
| | | S. G. | Vol. | S. G. | Vol. | S. G. | Vol. | S. G. | Vol. | S. G. | Vol. |
| 5 | 1:19.000 | 1031 | 31.03 | 1032 | 31.01 | 1032 | 31.01 | 1033 | 30.97 | 1034 | 30.95 |
| 6 | 1:15.667 | 1037 | 30.85 | 1036 | 30.82 | 1039 | 30.79 | 1040 | 30.76 | 1041 | 30.74 |
| 7 | 1:13.286 | 1044 | 30.66 | 1045 | 30.62 | 1046 | 30.59 | 1047 | 30.56 | 1048 | 30.53 |
| 8 | 1:11.500 | 1050 | 30.46 | 1052 | 30.43 | 1053 | 30.39 | 1055 | 30.36 | 1055 | 30.32 |
| 9 | 1:10.111 | 1057 | 30.27 | 1059 | 30.23 | 1060 | 30.19 | 1061 | 30.15 | 1063 | 30.11 |
| 10 | 1:9.000 | 1064 | 30.08 | 1065 | 30.03 | 1067 | 29.99 | 1068 | 29.95 | 1070 | 29.90 |
| 11 | 1:8.091 | 1071 | 29.88 | 1073 | 29.83 | 1074 | 29.79 | 1076 | 29.74 | 1078 | 29.69 |
| 12 | 1:7.333 | 1078 | 29.70 | 1080 | 29.64 | 1082 | 29.59 | 1083 | 29.53 | 1085 | 29.48 |
| 13 | 1:6.692 | 1085 | 29.50 | 1087 | 29.44 | 1089 | 29.39 | 1091 | 29.33 | 1093 | 29.27 |
| 14 | 1:6.144 | 1092 | 29.31 | 1094 | 29.24 | 1097 | 29.19 | 1099 | 29.12 | 1101 | 29.06 |
| 15 | 1:5.667 | 1099 | 29.18 | 1102 | 29.05 | 1104 | 28.99 | 1107 | 28.91 | 1109 | 28.85 |
| 16 | 1:5.250 | 1106 | 28.93 | 1109 | 28.85 | 1112 | 28.78 | 1115 | 28.71 | 1117 | 28.65 |
| 17 | 1:4.882 | 1114 | 28.74 | 1117 | 28.65 | 1119 | 28.58 | 1123 | 28.50 | 1125 | 28.44 |
| 18 | 1:4.556 | 1121 | 28.54 | 1125 | 28.45 | 1128 | 28.38 | 1131 | 28.30 | 1134 | 28.23 |
| 19 | 1:4.263 | 1129 | 28.35 | 1133 | 28.26 | 1136 | 28.18 | 1139 | 28.09 | 1142 | 28.02 |
| 20 | 1:4.000 | 1136 | 28.17 | 1140 | 28.06 | 1144 | 27.98 | 1147 | 27.89 | 1151 | 27.81 |
| 21 | 1:3.762 | 1144 | 27.97 | 1148 | 27.87 | 1152 | 27.77 | 1156 | 27.68 | 1159 | 27.60 |
| 22 | 1:3.545 | 1152 | 27.78 | 1157 | 27.67 | 1161 | 27.57 | 1165 | 27.47 | 1168 | 27.39 |
| 23 | 1:3.348 | 1160 | 27.58 | 1165 | 27.47 | 1169 | 27.37 | 1174 | 27.27 | 1177 | 27.18 |
| 24 | 1:3.167 | 1168 | 27.39 | 1173 | 27.27 | 1178 | 27.17 | 1182 | 27.06 | 1186 | 26.97 |
| 25 | 1:3.000 | 1176 | 27.21 | 1182 | 27.08 | 1187 | 26.97 | 1191 | 26.85 | 1195 | 26.76 |
| 26 | 1:2.846 | 1185 | 27.01 | 1190 | 26.88 | 1195 | 26.77 | 1201 | 26.65 | 1205 | 26.55 |
| 27 | 1:2.704 | 1193 | 26.82 | 1199 | 26.68 | 1205 | 26.56 | 1210 | 26.44 | 1215 | 26.34 |
| 28 | 1:2.571 | 1202 | 26.62 | 1209 | 26.49 | 1214 | 26.36 | 1220 | 26.24 | 1224 | 26.13 |
| 29 | 1:2.448 | 1211 | 26.43 | 1217 | 26.29 | 1223 | 26.16 | 1229 | 26.03 | 1234 | 25.92 |
| 30 | 1:2.333 | 1220 | 26.24 | 1226 | 26.10 | 1233 | 25.95 | 1239 | 25.83 | 1244 | 25.71 |
| 31 | 1:2.226 | 1229 | 26.05 | 1236 | 25.90 | 1242 | 25.75 | 1249 | 25.63 | 1255 | 25.50 |
| 32 | 1:2.125 | 1238 | 25.86 | 1245 | 25.70 | 1252 | 25.55 | 1259 | 25.42 | 1265 | 25.29 |
| 33 | 1:2.030 | 1247 | 25.66 | 1255 | 25.50 | 1262 | 25.35 | 1269 | 25.21 | 1276 | 25.08 |
| 34 | 1:1.940 | 1256 | 25.47 | 1264 | 25.31 | 1272 | 25.15 | 1279 | 25.01 | 1287 | 24.87 |
| 35 | 1:1.857 | 1266 | 25.28 | 1274 | 25.12 | 1283 | 24.95 | 1290 | 24.80 | 1298 | 24.66 |
| 36 | 1:1.778 | 1276 | 25.09 | 1284 | 24.91 | 1293 | 24.75 | 1301 | 24.60 | 1309 | 24.45 |
| 37 | 1:1.703 | 1285 | 24.90 | 1295 | 24.71 | 1304 | 24.55 | 1312 | 24.39 | 1320 | 24.24 |
| 38 | 1:1.632 | 1295 | 24.70 | 1305 | 24.52 | 1314 | 24.35 | 1323 | 24.19 | 1332 | 24.03 |
| 39 | 1:1.564 | 1305 | 24.51 | 1316 | 24.32 | 1326 | 24.14 | 1335 | 23.98 | 1343 | 23.82 |
| 40 | 1:1.500 | 1316 | 24.32 | 1326 | 24.13 | 1336 | 23.95 | 1346 | 23.77 | 1355 | 23.61 |
| 41 | 1:1.439 | 1326 | 24.13 | 1337 | 23.93 | 1348 | 23.74 | 1357 | 23.57 | 1367 | 23.40 |
| 42 | 1:1.381 | 1337 | 23.94 | 1348 | 23.73 | 1359 | 23.55 | 1370 | 23.36 | 1380 | 23.19 |
| 43 | 1:1.326 | 1348 | 23.74 | 1359 | 23.53 | 1371 | 23.34 | 1382 | 23.16 | 1392 | 22.99 |
| 44 | 1:1.273 | 1359 | 23.55 | 1372 | 23.33 | 1383 | 23.15 | 1395 | 22.95 | 1405 | 22.78 |
| 45 | 1:1.222 | 1370 | 23.36 | 1383 | 23.14 | 1395 | 22.94 | 1407 | 22.74 | 1418 | 22.57 |
| 46 | 1:1.174 | 1381 | 23.17 | 1395 | 22.94 | 1408 | 22.73 | 1420 | 22.54 | 1432 | 22.36 |
| 47 | 1:1.128 | 1393 | 22.98 | 1407 | 22.75 | 1420 | 22.54 | 1433 | 22.33 | 1445 | 22.15 |
| 48 | 1:1.083 | 1404 | 22.78 | 1419 | 22.55 | 1433 | 22.33 | 1446 | 22.12 | 1458 | 21.94 |
| 49 | 1:1.041 | 1416 | 22.59 | 1431 | 22.35 | 1446 | 22.13 | 1460 | 21.92 | 1473 | 21.73 |
| 50 | 1:1.000 | 1429 | 22.39 | 1444 | 22.15 | 1460 | 21.92 | 1473 | 21.71 | 1487 | 21.52 |
| 51 | 1:0.961 | 1441 | 22.21 | 1458 | 21.96 | 1473 | 21.72 | 1488 | 21.51 | 1502 | 21.31 |
| 52 | 1:0.923 | 1453 | 22.02 | 1471 | 21.76 | 1487 | 21.52 | 1502 | 21.30 | 1517 | 21.10 |
| 53 | 1:0.887 | 1466 | 21.82 | 1484 | 21.56 | 1501 | 21.32 | 1516 | 21.10 | 1532 | 20.89 |
| 54 | 1:0.852 | 1479 | 21.63 | 1498 | 21.36 | 1515 | 21.12 | 1532 | 20.89 | 1548 | 20.68 |
| 55 | 1:0.809 | 1493 | 21.44 | 1512 | 21.17 | 1530 | 20.92 | 1547 | 20.69 | 1564 | 20.47 |
| 56 | 1:0.786 | 1506 | 21.25 | 1526 | 20.97 | 1545 | 20.72 | 1563 | 20.48 | 1580 | 20.26 |
| 57 | 1:0.754 | 1520 | 21.06 | 1540 | 20.77 | 1560 | 20.51 | 1579 | 20.27 | 1596 | 20.05 |
| 58 | 1:0.724 | 1534 | 20.86 | 1555 | 20.58 | 1574 | 20.31 | 1595 | 20.07 | 1613 | 19.84 |
| 59 | 1:0.695 | 1548 | 20.67 | 1572 | 20.38 | 1591 | 20.11 | 1611 | 19.86 | 1629 | 19.63 |
| 60 | 1:0.667 | 1563 | 20.48 | 1585 | 20.18 | 1607 | 19.91 | 1628 | 19.66 | 1645 | 19.42 |
| 61 | 1:0.639 | 1577 | 20.29 | 1601 | 19.98 | 1623 | 19.71 | 1645 | 19.45 | 1664 | 19.21 |
| 62 | 1:0.613 | 1592 | 20.10 | 1617 | 19.79 | 1641 | 19.51 | 1662 | 19.25 | 1683 | 19.00 |
| 63 | 1:0.587 | 1608 | 19.90 | 1633 | 19.59 | 1657 | 19.30 | 1681 | 19.04 | 1703 | 18.79 |
| 64 | 1:0.563 | 1623 | 19.71 | 1650 | 19.40 | 1675 | 19.10 | 1698 | 18.84 | 1723 | 18.58 |
| 65 | 1:0.538 | 1639 | 19.52 | 1667 | 19.20 | 1692 | 18.90 | 1718 | 18.73 | 1742 | 18.37 |
| 66 | 1:0.515 | 1656 | 19.32 | 1684 | 19.00 | 1711 | 18.70 | 1738 | 18.53 | 1762 | 18.16 |
| 67 | 1:0.493 | 1672 | 19.14 | 1701 | 18.80 | 1730 | 18.50 | 1757 | 18.32 | 1783 | 17.95 |
| 68 | 1:0.471 | 1689 | 18.94 | 1719 | 18.61 | 1749 | 18.30 | 1776 | 18.11 | 1803 | 17.74 |
| 69 | 1:0.449 | 1706 | 18.75 | 1738 | 18.41 | 1768 | 18.10 | 1797 | 17.81 | 1825 | 17.53 |
| 70 | 1:0.429 | 1724 | 18.56 | 1757 | 18.21 | 1786 | 17.90 | 1818 | 17.60 | 1847 | 17.32 |

SLIME DENSITY RELATIONS.

| | | Specific Gravity of Pulp and Volume of One Ton in Cubic Feet, for Slimes Containing Solids of Different Specific Gravities. | | | | | | | | | |
|--------------------|------------------------------|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Per Cent. So. ids. | Ratio of Solids to Solution. | 3.00 | | 3.10 | | 3.20 | | 3.30 | | 4.50 | |
| | | S. G. | Vol. | S. G. | Vol. | S. G. | Vol. | S. G. | Vol. | S. G. | Vol. |
| 5 | 1:19.000 | 1035 | 30.93 | 1035 | 30.92 | 1036 | 30.90 | 1036 | 30.89 | 1040 | 30.76 |
| 6 | 1:15.667 | 1042 | 30.72 | 1042 | 30.70 | 1043 | 30.68 | 1043 | 30.66 | 1049 | 30.51 |
| 7 | 1:13.286 | 1049 | 30.51 | 1049 | 30.48 | 1050 | 30.46 | 1051 | 30.43 | 1058 | 30.26 |
| 8 | 1:11.500 | 1056 | 30.30 | 1057 | 30.27 | 1058 | 30.24 | 1059 | 30.21 | 1067 | 30.01 |
| 9 | 1:10.111 | 1064 | 30.09 | 1065 | 30.05 | 1066 | 30.02 | 1067 | 29.99 | 1075 | 29.76 |
| 10 | 1:9.000 | 1071 | 29.87 | 1072 | 29.83 | 1074 | 29.80 | 1075 | 29.77 | 1084 | 29.51 |
| 11 | 1:8.091 | 1078 | 29.65 | 1080 | 29.61 | 1082 | 29.58 | 1083 | 29.54 | 1093 | 29.26 |
| 12 | 1:7.333 | 1087 | 29.44 | 1088 | 29.40 | 1090 | 29.36 | 1091 | 29.32 | 1102 | 29.01 |
| 13 | 1:6.692 | 1095 | 29.23 | 1096 | 29.18 | 1098 | 29.14 | 1099 | 29.10 | 1112 | 28.76 |
| 14 | 1:6.144 | 1103 | 29.01 | 1105 | 28.96 | 1106 | 28.92 | 1108 | 28.88 | 1122 | 28.52 |
| 15 | 1:5.667 | 1111 | 28.80 | 1113 | 28.74 | 1115 | 28.70 | 1117 | 28.66 | 1132 | 28.27 |
| 16 | 1:5.250 | 1119 | 28.59 | 1122 | 28.53 | 1124 | 28.48 | 1125 | 28.43 | 1142 | 28.02 |
| 17 | 1:4.882 | 1128 | 28.37 | 1130 | 28.31 | 1132 | 28.26 | 1134 | 28.21 | 1152 | 27.77 |
| 18 | 1:4.556 | 1136 | 28.16 | 1139 | 28.10 | 1141 | 28.04 | 1143 | 27.99 | 1163 | 27.52 |
| 19 | 1:4.263 | 1145 | 27.95 | 1148 | 27.88 | 1150 | 27.82 | 1153 | 27.76 | 1173 | 27.27 |
| 20 | 1:4.000 | 1154 | 27.73 | 1157 | 27.66 | 1159 | 27.60 | 1162 | 27.54 | 1184 | 27.02 |
| 21 | 1:3.762 | 1163 | 27.52 | 1166 | 27.44 | 1169 | 27.38 | 1171 | 27.32 | 1194 | 26.77 |
| 22 | 1:3.545 | 1172 | 27.31 | 1175 | 27.23 | 1178 | 27.16 | 1181 | 27.09 | 1206 | 26.52 |
| 23 | 1:3.348 | 1181 | 27.09 | 1184 | 27.01 | 1188 | 26.94 | 1191 | 26.87 | 1218 | 26.28 |
| 24 | 1:3.167 | 1190 | 26.88 | 1194 | 26.79 | 1198 | 26.72 | 1201 | 26.65 | 1230 | 26.03 |
| 25 | 1:3.000 | 1200 | 26.67 | 1204 | 26.58 | 1208 | 26.50 | 1211 | 26.42 | 1241 | 25.78 |
| 26 | 1:2.846 | 1210 | 26.45 | 1214 | 26.37 | 1218 | 26.28 | 1222 | 26.20 | 1253 | 25.53 |
| 27 | 1:2.704 | 1220 | 26.24 | 1224 | 26.15 | 1228 | 26.06 | 1232 | 25.98 | 1266 | 25.28 |
| 28 | 1:2.571 | 1230 | 26.03 | 1234 | 25.93 | 1239 | 25.84 | 1242 | 25.75 | 1278 | 25.03 |
| 29 | 1:2.448 | 1240 | 25.81 | 1244 | 25.71 | 1249 | 25.62 | 1253 | 25.53 | 1291 | 24.78 |
| 30 | 1:2.333 | 1250 | 25.60 | 1255 | 25.50 | 1260 | 25.40 | 1264 | 25.31 | 1304 | 24.03 |
| 31 | 1:2.226 | 1261 | 25.39 | 1266 | 25.28 | 1271 | 25.18 | 1275 | 25.08 | 1317 | 24.24 |
| 32 | 1:2.125 | 1271 | 25.17 | 1277 | 25.05 | 1282 | 24.96 | 1287 | 24.86 | 1331 | 24.04 |
| 33 | 1:2.030 | 1282 | 24.96 | 1288 | 24.85 | 1293 | 24.74 | 1299 | 24.64 | 1345 | 23.79 |
| 34 | 1:1.940 | 1293 | 24.75 | 1299 | 24.63 | 1305 | 24.52 | 1311 | 24.41 | 1359 | 23.54 |
| 35 | 1:1.857 | 1304 | 24.53 | 1310 | 24.41 | 1317 | 24.30 | 1323 | 24.19 | 1374 | 23.29 |
| 36 | 1:1.778 | 1316 | 24.32 | 1322 | 24.19 | 1329 | 24.08 | 1335 | 23.97 | 1389 | 23.04 |
| 37 | 1:1.703 | 1328 | 24.11 | 1334 | 23.98 | 1341 | 23.86 | 1347 | 23.75 | 1404 | 22.79 |
| 38 | 1:1.632 | 1340 | 23.89 | 1346 | 23.76 | 1353 | 23.64 | 1360 | 23.52 | 1420 | 22.54 |
| 39 | 1:1.564 | 1351 | 23.68 | 1358 | 23.55 | 1366 | 23.42 | 1373 | 23.30 | 1435 | 22.29 |
| 40 | 1:1.500 | 1363 | 23.47 | 1371 | 23.33 | 1379 | 23.20 | 1387 | 23.08 | 1451 | 22.04 |
| 41 | 1:1.439 | 1376 | 23.26 | 1384 | 23.13 | 1393 | 22.98 | 1400 | 22.85 | 1468 | 21.79 |
| 42 | 1:1.381 | 1389 | 23.04 | 1397 | 22.89 | 1406 | 22.76 | 1414 | 22.63 | 1485 | 21.55 |
| 43 | 1:1.326 | 1402 | 22.83 | 1411 | 22.68 | 1419 | 22.54 | 1428 | 22.41 | 1502 | 21.30 |
| 44 | 1:1.273 | 1415 | 22.61 | 1425 | 22.46 | 1433 | 22.32 | 1442 | 22.18 | 1519 | 21.05 |
| 45 | 1:1.222 | 1429 | 22.40 | 1438 | 22.24 | 1447 | 22.10 | 1456 | 21.96 | 1538 | 20.80 |
| 46 | 1:1.174 | 1443 | 22.19 | 1452 | 22.02 | 1462 | 21.88 | 1471 | 21.74 | 1557 | 20.55 |
| 47 | 1:1.128 | 1457 | 21.97 | 1467 | 21.81 | 1477 | 21.66 | 1487 | 21.51 | 1576 | 20.30 |
| 48 | 1:1.083 | 1471 | 21.76 | 1483 | 21.60 | 1493 | 21.44 | 1503 | 21.29 | 1595 | 20.05 |
| 49 | 1:1.041 | 1485 | 21.55 | 1497 | 21.38 | 1508 | 21.22 | 1519 | 21.07 | 1615 | 19.81 |
| 50 | 1:1.000 | 1500 | 21.33 | 1512 | 21.16 | 1524 | 21.00 | 1535 | 20.85 | 1637 | 19.56 |
| 51 | 1:0.961 | 1515 | 21.12 | 1528 | 20.94 | 1540 | 20.78 | 1551 | 20.62 | 1658 | 19.31 |
| 52 | 1:0.923 | 1531 | 20.91 | 1544 | 20.73 | 1556 | 20.56 | 1568 | 20.40 | 1679 | 19.06 |
| 53 | 1:0.887 | 1547 | 20.69 | 1560 | 20.51 | 1573 | 20.34 | 1585 | 20.18 | 1700 | 18.81 |
| 54 | 1:0.852 | 1563 | 20.48 | 1577 | 20.29 | 1590 | 20.12 | 1603 | 19.96 | 1724 | 18.56 |
| 55 | 1:0.809 | 1579 | 20.27 | 1594 | 20.08 | 1608 | 19.90 | 1621 | 19.73 | 1748 | 18.31 |
| 56 | 1:0.786 | 1596 | 20.05 | 1611 | 19.87 | 1626 | 19.68 | 1640 | 19.51 | 1772 | 18.06 |
| 57 | 1:0.754 | 1613 | 19.84 | 1628 | 19.65 | 1645 | 19.46 | 1659 | 19.29 | 1796 | 17.81 |
| 58 | 1:0.724 | 1631 | 19.63 | 1646 | 19.43 | 1663 | 19.24 | 1678 | 19.06 | 1822 | 17.56 |
| 59 | 1:0.695 | 1649 | 19.41 | 1665 | 19.21 | 1682 | 19.02 | 1697 | 18.84 | 1848 | 17.32 |
| 60 | 1:0.667 | 1667 | 19.20 | 1684 | 19.00 | 1702 | 18.80 | 1718 | 18.62 | 1875 | 17.07 |
| 61 | 1:0.639 | 1686 | 18.99 | 1704 | 18.78 | 1722 | 18.58 | 1739 | 18.39 | 1903 | 16.82 |
| 62 | 1:0.613 | 1705 | 18.77 | 1724 | 18.56 | 1742 | 18.36 | 1761 | 18.17 | 1932 | 16.57 |
| 63 | 1:0.587 | 1724 | 18.56 | 1745 | 18.34 | 1764 | 18.14 | 1783 | 17.95 | 1961 | 16.32 |
| 64 | 1:0.563 | 1745 | 18.35 | 1765 | 18.12 | 1786 | 17.92 | 1805 | 17.72 | 1992 | 16.07 |
| 65 | 1:0.538 | 1765 | 18.13 | 1786 | 17.91 | 1808 | 17.70 | 1828 | 17.50 | 2023 | 15.82 |
| 66 | 1:0.515 | 1786 | 17.92 | 1808 | 17.69 | 1830 | 17.48 | 1852 | 17.28 | 2054 | 15.57 |
| 67 | 1:0.493 | 1808 | 17.71 | 1831 | 17.47 | 1853 | 17.24 | 1875 | 17.06 | 2088 | 15.32 |
| 68 | 1:0.471 | 1830 | 17.49 | 1854 | 17.26 | 1877 | 17.04 | 1901 | 16.83 | 2123 | 15.08 |
| 69 | 1:0.449 | 1852 | 17.28 | 1878 | 17.06 | 1902 | 16.82 | 1927 | 16.61 | 2159 | 14.83 |
| 70 | 1:0.429 | 1875 | 17.07 | 1902 | 16.83 | 1926 | 16.60 | 1953 | 16.39 | 2195 | 14.58 |

Electric Steel Refining Before the American Iron and Steel Institute

THE general meeting of the American Iron & Steel Institute, held on May 17 and 18, was particularly successful and interesting on account of the careful balance struck between the different functions which the Institute strives to perform in its discussions of commercial problems, in its examination of technical matters, in its devotion to welfare work and the labor problem in general, and in the general social intercourse between its members, which has done so much to weld the constituents of the American iron and steel industry into a harmonious unit.

The morning session of May 17 was opened by an able address of the president, Judge E. H. Gary, on the general situation. The commercial side of the program was covered by an excellent paper by Mr. E. A. S. Clarke, president of the Lackawanna Steel Co., on "Contract Obligations," and by an interesting paper by Mr. Joseph G. Butler, Jr., vice-president of the Brier Hill Steel Co., on "Competition, Its Uses and Abuses." Both papers elicited considerable discussion.

The evening session, taking the form of a banquet at the Waldorf-Astoria, gave the opportunity for a discussion of welfare and safety work. Particularly notable were a paper by Dr. Thomas Darlington, on the enforcement of health laws, and an address by Mr. Raynal C. Bolling, on "Rendering Labor Safe."

The afternoon session of May 17 was devoted to technical papers. Mr. Julian Kennedy spoke on "Some Experiences in India," Dr. John S. Unger, of the Carnegie Steel Co., on "Metals and Alloys," Dr. A. S. Cushman on "Corrosion."

Of chief interest was, however, the paper by Mr. William R. Walker, of the U. S. Steel Corporation, on electric steel refining. This paper is here given in full, together with an account of the discussion which followed. We comment on the paper on our editorial pages.

The Electric Furnace as a Possible Means of Producing an Improved Quality of Steel.

BY WILLIAM R. WALKER

United States Steel Corporation.

In the manufacture of steel by either the Bessemer or open hearth process, it is very difficult to remove the last traces of oxygen. In the basic Bessemer process, the overblown metal, which is an extreme case of oxidation, contains only .06 per cent of oxygen.* Oxygen in combination with carbon (carbon monoxide), silicon, iron, aluminum and manganese, and also the combinations of silicates with these oxides, are very deleterious in steel.

My investigations lead me to believe that in the manufacture of steel for the so-called heavy products and steel that is produced in large quantities, a combination of either the acid or basic Bessemer converter and the electric furnace will take a very prominent place. With this combination it is possible to produce steel extremely low in oxygen and other impurities at a cost that will not be prohibitive.

At the present time there are over 70 electric furnaces of various types producing electric steel in Europe and America. These range in capacity from 1 to 15 tons. There is now under construction in Germany a furnace of 25 tons' capacity. A number of these furnaces are competing successfully with crucibles in the manufacture of very high grade steel.

Generally speaking, electric furnaces may be divided into two groups:

First, induction furnaces, in which the heat is supplied by a current induced in the bath.

Second, arc furnaces, in which the arc is struck, either between an electrode and the metal in the bath, or between two or more electrodes so as to heat the metal only by radiation from the arc.

In operating the electric furnace at the present time, the most prominent methods or combinations are as follows:

1. Oxidation of silicon, carbon and manganese in an acid lined Bessemer converter and removing the phosphorus in the basic lined electric furnace with an oxidizing slag and then recarburizing and with the aid of manganese and carbon and a new reducing slag removing oxygen and sulphur and dead melting as in the crucible process.

2. Removal of silicon, carbon, manganese and phosphorus in a basic lined Bessemer converter and further removing phosphorus (if desired) in the basic lined electric furnace with an oxidizing slag, and then with the aid of manganese and carbon and a new reducing slag removing oxygen and sulphur and dead melting as in the crucible process.

3. Removal of silicon, carbon, manganese and phosphorus in the basic open hearth furnace and then recarburizing and in the basic lined electric furnace with the aid of manganese and carbon and a new reducing slag removing oxygen and sulphur and dead melting as in the crucible process.

4. Melting of cold scrap of inferior quality in a basic lined electric furnace; removing phosphorus with an oxidizing slag and then recarburizing and with the aid of manganese and carbon and with a new reducing slag removing oxygen and sulphur and dead melting as in the crucible process.

5. Melting high grade materials in the electric furnace and dead melting as in the crucible process.

The phosphorus is removed in the basic electric furnace in the same manner as in the basic open hearth furnace—that is, by the use of lime and oxide of iron—and the resulting slag containing the phosphorus is removed and a new slag formed consisting of burnt lime and fluor spar; and when the slag is melted, coke dust is added, which, coming in contact with the lime in the slag and the electric arc, produces carbide of calcium. The free carbon and possibly the carbide of calcium in the slag, with the aid of carbon and manganese in the bath, eliminate the oxygen from the steel.

As compared with the Bessemer and basic open hearth processes, the electric has the following advantages:

1. The more complete removal of oxygen.
2. The absence of oxides caused by the additions, such as silicon, manganese, etc.
3. The production of electric steel ingots of eight tons in weight and smaller that are practically free from segregation.
4. Reduction of sulphur to .005 per cent, if desired.
5. Reduction of phosphorus to .005 per cent, as in the basic open hearth process, but with the complete removal of oxygen.

As evidence of the reducing properties of the slag in the basic electric furnace, it has been found that if oxide of manganese and oxide of iron are thrown on the molten slag, the oxides are reduced to the metallic state and the reduced metal goes into the bath. Blown metal from the acid Bessemer converter, containing only .10 per cent to .20 per cent manganese, has been completely deoxidized in the electric furnace without addition of manganese or aluminum, the usual amount of silicon being added in the steel ladle. Rails made from this steel

* "The Non-Metallic Impurities in Steel"—F. F. Law. "The Journal of the Iron & Steel Institute"—Volume II, Year 1907.

are now in service. The composition of one heat of this steel is as follows:

| | Per Cent. |
|------------------|-----------|
| Carbon | .55 |
| Manganese | .13 |
| Sulphur | .017 |
| Silicon | .19 |
| Phosphorus | .022 |

These rails are comparatively soft, but are showing superior wearing qualities compared with the Bessemer rails in the same track and under the same service conditions.

Electric steel ingots crack much less in rolling than either Bessemer or basic open hearth steel. Cold electric steel ingots when heated and rolled into rails, roll extremely well.

At the present time there are approximately 5,600 tons of standard electric steel rails in service in the United States. These rails have been in the track about two years. During the past winter some of these rails have been subjected to very low temperatures—in some cases as low as 52° below zero, Fahrenheit, and are being exposed to all the possible conditions of severe service. It is too early to state much about the wearing qualities of these rails, but from present indications it would appear that rails made by the basic electric process can be made somewhat softer than by either the Bessemer or basic open hearth process and show highly satisfactory wearing qualities. Up to the present time we have not heard of any basic electric rails in use in this country being broken in service.

For experimental purposes, I have had made a small tonnage of electric steel rails, which have varied in analysis as follows:

| | Per Cent. |
|------------------|------------|
| Carbon | .50 to .75 |
| Manganese | .13 to .80 |
| Silicon | .10 to .40 |
| Phosphorus | .02 to .06 |

On account of the wide variation in the chemical composition of this steel, it would in a paper of this nature and with the limited time at my disposal, be difficult, without going into considerable detail, to discuss the physical properties of these rails. It might be stated, however, that electric steel of a given tensile strength has a slightly greater amount of elongation than basic open hearth steel and that electric steel is somewhat denser than basic open hearth or Bessemer steel.

With the electric furnace, it is possible to produce steel, which when magnified one thousand diameters, shows no oxides or slag enclosures.

As high grade electric steel can be produced at a lower cost than crucible steel, there has been a gradual increase in the production of electric steel for certain purposes where crucible steel was formerly employed and where it has been demonstrated electric steel can be successfully used. This increased production has not been so marked where the object has been the improvement of steel entering into products manufactured in large quantities where the expense involved for experimental work is very great and where of necessity it takes several years to demonstrate if rails and other products made by the electric process are superior to those made by either the Bessemer or open hearth process. From present indications, it would seem probable that there will be a decided increase in the production of electric steel for these products in the near future.

DISCUSSION.

Mr. Walker's paper elicited quite an interesting discussion, in which Mr. T. W. Robinson, vice-president of the Illinois Steel Co., and Mr. Eugene B. Clark, of the American Sintering Co., participated.

The secretary read a communicated discussion by Mr. S. T. Wellman, of the Wellman-Seaver-Morgan Co., and formerly of the famous Otis Steel Co.

Electric Steel for Rails.

Mr. S. T. Wellman's communicated discussion was as follows:

"I have been very much interested in reading Mr. Walker's paper. It confirms my own observations as to the new method of refining steel and making an article that is of the very highest quality in every respect.

"We have heard a great deal in years gone by of the necessity, if high-class steel was wanted, of melting it in a reducing atmosphere, but this has never been possible in the furnaces which we had at our command because with the reducing atmosphere there came reduction of temperature too low for the proper melting of the steel, but with the electric furnace all these conditions are changed, and we can get the highest temperature known in the arts without the presence of any free oxygen whatever.

"The electrical furnace makes possible the production of ideal steel for any purpose whatever, whether it be the softest steel used for high-grade sheets or plates, medium steel for axles and shafts, rail steel, or any of the numerous grades of ordinary tool steel, or for high-speed alloy tool steel, or projectile steel.

"I think that the most important use that electrically refined steel can be put to is the manufacture of rail steel. The railroads of this country have been learning some very costly lessons during the past few months as regards steel rail specifications, and it would seem that now they should be ready to buy the best and safest rail that can be made without regard to a slightly higher price or possibly a little more rapid wear.

"Rails made from electrically refined steel seem to me to offer the very best solution to the problem, for the following reasons:

"1. An ingot is produced which from all the evidence we have is almost perfect in structure. There is almost an absolute freedom from blow-holes which is caused by the freedom of liquid steel from oxides and gases of all kinds; but, what is most important, ingots as large as eight tons, as mentioned by Mr. Walker, can be made which are practically free from segregation. Mr. Walker's statements in regard to this confirm my own observations.

"2. The ingot can be made practically free from phosphorus and sulphur, and on account of its freedom from oxides and gases little or no manganese is necessary in the steel; thus the steelmaker is able to make the ideal steel which is absolutely free from deleterious impurities, and contains nothing but iron and the carbon to give it the necessary hardness for wear. It will probably be found that on account of its greater density not as much carbon will be necessary to give it good wearing qualities, as is the case in ordinary Bessemer or open hearth steel.

"3. On account of its freedom from oxides and gases, there is almost perfect freedom from cracking in rolling. This must make a better rail on account of more perfect surface and freedom from little imperfections which start the wear and are also good starting places for cracks.

"4. The most valuable peculiarity in electrical steel seems to me to be its freedom from segregation. Most, if not all, the failure of rails during the last winter have been practically on account of bad defects caused by piped ingots, the defects from which were not discovered in the blooms nor in the finished rails.

"I think it more than likely that it may be found that the best rail steel if made from the electrical furnace can be made by making small additions of some of the numerous metals used as alloys, like chromium, titanium, nickel, vanadium or tungsten. The effect of these different metals on steel is not yet generally understood, but it offers a very attractive field for study and experiment. From my own observations, I think that a small percentage of chromium, not to exceed 0.25 per cent and a very much smaller amount of titanium would have a very good effect on the density of the rail, and would at the same time toughen and strengthen the steel.

"Some of the gentlemen present may say to me, as my friend, Captain William R. Jones, did to William A. Sweet when he came down to Pittsburgh many years ago to the meeting of one

of the engineering societies to tell them how to make good rails. Said Captain Bill: 'What do you know about making rails? You never made any,' which would be a good criticism of anything I might say about this subject, so I will stop right here."

Electric Steel Furnace Experience at South Chicago.

Mr. T. W. ROBINSON, vice-president of the Illinois Steel Co., referred to the fact that three years ago the 15-ton basic lined Heroult furnace erected at the South Chicago works of the Illinois Steel Company* made its first heat. At that time it was the largest electric furnace in existence, and none of greater capacity has as yet been put into operation, although there are several 20 or 25 ton furnaces in Europe now under construction.

"The application of electricity to the manufacture of steel is, commercially speaking, a new process, and the installation at South Chicago was a new adaptation of this new process. Our purpose was to demonstrate whether it was feasible to successfully operate a large electric furnace and make electric steel in large tonnages. At the time the South Chicago furnace was started, the electric furnaces used in the manufacture of steel here and abroad were small, running from a ton or less to five tons in capacity. The aim in their development was largely to find a cheaper process than the crucible process. Our aim was to command a superior steel, and if possible at a cost that would permit of its use in such products as rails. Our problems, mechanical, metallurgical and otherwise, proved many, and our experience soon demonstrated that the conditions surrounding the successful operation of a large electric furnace were in many respects entirely different from those involved in the use of smaller units. In illustration, the demands of a 15-ton electric furnace proved to be far in advance of the art of manufacturing electrodes. Our necessities represented a requirement that the electrode manufacturers of America and Europe had not been called upon to meet, and it took much time and money before there was finally accomplished the 20-inch round amorphous carbon electrode that is now being used at South Chicago."

"While in the application of the electric furnace to the metallurgy of steel there is usually embodied the preliminary removal of impurities by oxidation, the thermal and chemical conditions that obtain are unusually favorable to the final purification of the metal. Although it has proved perfectly feasible to make steel of superior quality from even low grade cold material, the usual practice at South Chicago is to refine in the electric furnace full-blown metal from the Bessemer converter.

"While the electric furnace at South Chicago has probably operated on a greater variety of products than any other furnace in the world, especial attention has been given to the production of electric steel for rails. As Mr. Walker has stated, the results have been most promising.

"The steel in teeming lies much more quietly than is ordinarily the case with open hearth or Bessemer. The ingots when split show a very solid metal, with a remarkable freedom from blowholes. The pipe, unless filled, is as deep as with open hearth or Bessemer steel. Segregation is at a minimum, and the steel is exceptionally homogeneous. Chemically speaking, almost any result within reasonable limits can be obtained. Physically, the metal is more dense than either open hearth or Bessemer. In its ultimate strength and elongation for the same carbon, there is but little difference between electric and open hearth in the higher carbons. In the lower carbons, electric steel has a tendency to a higher tensile and a possibly somewhat lower elongation.

"Many etched sections of rails indicate that the steel from the electric furnace is peculiarly uniform in structure, and it appears to be exceptionally free from oxide and slag enclosures as partially determined by microscopic examination. In fact, such superiority as electric steel may have, probably largely lies in its relative freedom from oxygen.

"How much there may be in the theory advanced by some that the characteristics of electric steel are partially due to the influence of the peculiar thermal conditions upon its molecular structure, I cannot say. Certain indications, however, point to there being more in this hypothesis than is generally recognized.

"As Mr. Walker has stated, we have thus far received no report of any breakage from the 5,600 tons of standard steel rails that we have shipped. Some of these rails have been in track for two and a half years or more. Some of the first rails that we produced were intentionally made upon the soft side, running as low as 0.55 in carbon. Our later electric rails, of which the laboratory results would indicate a relatively better wearing quality, have been made ten or more points higher in carbon.

"I recognize that on account of the comparatively short time that the electric rail has been in service, any statement in respect to its comparative quality is open to question. Of course, the final verdict on the merits of any steel must be in that metallurgical court of last resort—result in service. But whatever may be the verdict, American steel practice and the public must be the gainers from the extensive work that has been done in the endeavor to produce, through the electric furnace, a rail of superior quality."

Various Types and Applications of Electric Steel Furnaces.

Mr. EUGENE B. CLARK, of the American Sintering Co., referred to the hypothesis that the heat treatment of molten steel may have an effect upon its subsequent quality. "If this is so, the type of electric furnace in which the steel is refined must be taken into consideration, for the method of the application of heat to the molten steel differs considerably in the different types of furnaces."

Mr. Clark briefly sketched the relative advantages and disadvantages of induction furnaces and arc furnaces, both of the submerged arc type and of the surface arc type. "The submerged arc furnace is more extravagant of electrodes but less severe on linings than is the surface arc type, but on the other hand the heat is localized under the electrode in the former case and distributed over the whole bath in the latter case. What influence, if any, this heat distribution has upon the quality of steel is open to argument, and no effort is intended here to venture an opinion, but certainly this subject is of sufficient interest to warrant study. There are few cases when a steel manufacturer has tried more than one type of furnace."

Mr. Clark referred briefly to the production of high-grade steel in the electric furnace in competition with the crucible process and pointed out that "for certain foundry operations electrically refined steel is especially adapted. Small steel castings require a very hot metal and one free from slags and gases. The baby Bessemer gives a hot steel but one which runs high in oxides and often high in sulphur, so castings are apt to have blowholes and cracks. High manganese and high carbon contents are required to give sound castings, so annealing generally is necessary. The electric furnace obviates these objections by giving a metal at once hot enough to pour into thin molds, and still perfectly free from slags and gases. Metal of exactly the required composition may be obtained, and alloys of any desired analysis may be formed." Mr. Clark explained finally why electric heat must always be relatively expensive.

The Joseph Dixon Crucible Co. of Jersey City, N. J., has recently issued pamphlets on lubrication and especially on the use of Ticonderoga flake graphite as a lubricant. Reference is made to a statement by Prof. Goss to this effect: "The tests show that with no other lubrication than flake graphite the journal and brass may be run together for hours at a time, heating up to a high temperature, and this may be done repeatedly, and yet the rubbing surfaces of the bearings remain unscored. As a protection against abrasion of rubbing surfaces, I know of nothing that can equal the record of flake graphite."

* For illustrated description of this furnace see this journal, vol. VIII, p. 179 (April, 1910).

Recent Metallurgical and Chemical Patents.

Iron and Steel.

Filtering Furnace Gases.—Various means have been proposed to purify furnace gases where they are used for heating purposes or for the driving of gas engines. Water sprays and centrifugal force have been used in wet processes, and metallic screen filters have been proposed for dry filtration. According to the specifications of a patent granted to FRIEDRICH MÜLLER, OTTO JOHANNSEN and PETER PAPE, of Brebach-on-the-Saar, Ger-

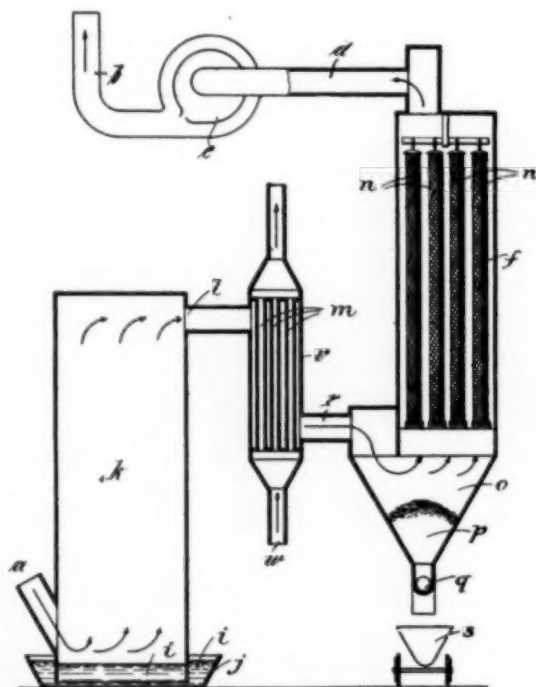


FIG. 1.—FILTERING FURNACE GASES.

many, there are serious objections to the use of these methods, and they propose a new scheme which they claim is an improvement on old methods.

The improved process admits of the use of fibrous material of animal or vegetable origin for filters, provided the temperature and moisture content of the furnace gases is closely regulated. They claim that foreign matter can be eliminated so that the gases will contain only 5 mg of such substances per cubic meter of gas. It is essential that the filter should not be subjected to variations in temperature, and, therefore, the gases are first cooled to the dew point. But as the dew point of the gases is usually higher than atmospheric temperature, it is not advisable to pass the gases directly to the filters without first slightly raising their temperature, in order that the filters shall not become clogged by water and solids which would be deposited at the dew point of the gas. Therefore a restricted heating process is introduced, after cooling to the dew point, before the gases are filtered. The reheating must be sufficient to raise the gas temperature about 20 deg. C. above its dew point. In order further to protect the filters from destruction by dry heat, the gases are damped in the cooling process, by allowing them to come in contact with a surface of water in the cooler.

In Fig. 1 is shown apparatus for cooling, reheating and filtering furnace gases according to the present invention. The cooler *k* is shown in a vessel of water, the latter forming a seal against the escape of the gases. The reheater is shown at *v*, and the filter at *f*. A fan *c* serves to draw the gases through the apparatus and deliver them by *b* to the point of application. Accumulated dust is removed through the hopper *o*. The path of the gas is from *a* through the cooler, reheater and filter to *b*.

The inventors give examples of conditions in German works, one of which is presented herewith, viz., the Halberger foundry.

Coke used per ton of pig iron, about 1300 kg.

Ore yielding about 31 per cent pig iron, 3230 kg.

Water contained in coke, 8-9 per cent. Water contained in ore, 8-10 per cent.

Gas evolved from coke, about 4 cu. m. per kg.

Water contained in charge, 1300 kg. coke \times 9 per cent + 3230 kg. ore \times 10 per cent = 440 kg.

Gas evolved, $1300 \times 4 = 5200$ cu. m.

440,000

Moisture in gas, $\frac{5200}{440,000} = 85$ gr. per cu. m.

Dew point, 50°C. This gas would be reheated to about 70°C. before filtering. (1,022,496, Apr. 9, 1912.)

Gold and Silver.

Aeration in Cyanidation.—In our issue for April, 1912, page 203, MR. LOUIS COHEN presented some miscellaneous cyanide experiments. One of the experiments dealt with the value of aeration of sand charges, alternating percolation with aeration. The results obtained showed the greater value of an intermittent process as compared with one of continuous leaching. As a result of these experiments, MR. COHEN and MR. JOHN GROSS, both of Denver, Colo., designed and patented an apparatus for carrying out their ideas on alternate leaching and aeration in comparatively thin beds of sand. The apparatus is shown in Fig. 5.

It consists of a circular tank having an annular filter bed on which the sand charge is deposited in a uniform manner by a rotating distributor. While the sand pulp is being distributed on the bed, the solution is drawn through the filter by means of a vacuum pump, and when the bed has been built up to the required thickness, the flow of pulp is turned off. Following this a flow of cyanide solution is allowed to pass over the charge from the rotating distributor, the vacuum being still in effect. In this manner fresh solution is passed through the charge at intervals determined by the speed of rotation of the distributor, and during these intervals air is drawn through the charge, thus effecting an alternating leaching and aeration. When extraction has been completed by this means, a wash of water may be applied to remove the remaining cyanide solution, and finally the extracted charge may be sluiced out of the tank, through an annular opening at the center of the tank bottom. By means of an adjustable plow and water pipe attached to the arm of the distributor (not shown in the cut), the sluicing of the charge is facilitated.

In Fig. 5 the source of ore pulp is shown at 30, the pulp being received in a bowl attached to the central shaft at 29, and distributed by the pipe 34 and apron 35 to the distributing rolls 37. A pipe for conducting cyanide solution to the charge is shown at 31. The distributor travels on wheels running on annular tracks as shown. (1,021,248, March 26, 1912.)

Filter Press Indicator.—For the purpose of enabling an operator to know the thickness of cake being deposited on a filter leaf in the enclosed type of slime filters, MR. DAVID J. KELLY, of Salt Lake City, Utah, has invented the indicator described herewith and illustrated in Fig. 6. The figure shows diagrammatically a drum containing filter leaves on which a slime cake may be made to form by forcing slime pulp into the drum, the liquid portion being removed through the filtering medium and the pipes *m*. As the operation is not visible to the eye of the operator, an indicator has been devised to show the amount of slime deposited, and thereby the point at which filtration should stop. The indicator consists of a small filter leaf *a*, similar in construction to the large leaves, connected by pipes *d* with a head *c*. On the opposite side of the head *c* is a float *b*. The filter and float being thus at opposite ends of a pivoted connection, they are free to turn about the pivot which consists of a pipe *f* extending through

the drum at *e*. To the outer portion of this pivot pipe is fixed an arm or pointer *g*, upon which is mounted an adjustable weight *j*. A graduated quadrant is placed as shown. The pivot pipe *f* may have a flexible attachment to direct the solution flowing from the small filter to any desirable place.

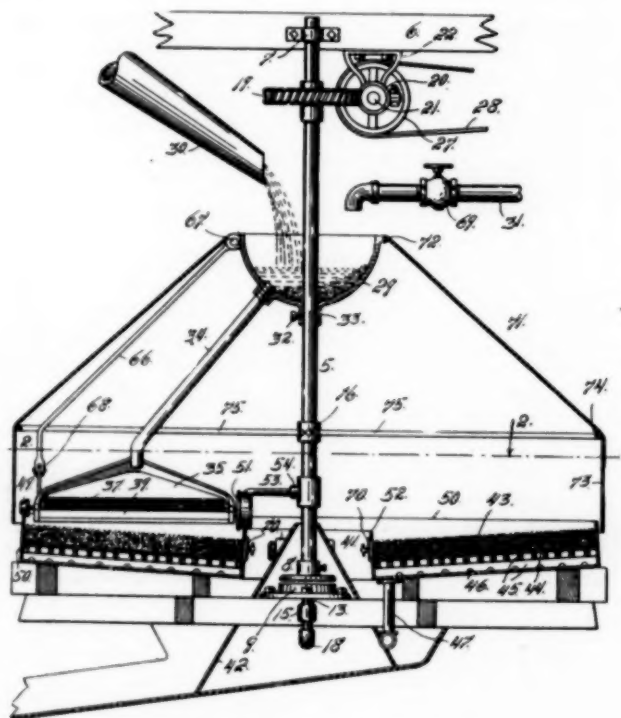


FIG. 5.—AERATION IN CYANIDATION.

It will be apparent from this description that when the drum is filled with slime pulp and cakes begin to form on the large leaves, a similar cake will form on the small leaf *a*; and as the cake continues to form, the leaf will sink by reason of its increased weight, and cause the pointer on the outside to register the thickness of the accumulated cake. The float is so proportioned as to neutralize the effect of the force of buoyancy on the cake, being made to correspond relatively to the cubical contents of the cake and the distance from the fulcrum.

While the invention is described in connection with a pressure filter, it is apparent that it can be applied to vacuum filters by connecting the flexible connection *i* with a suitable branch of the suction line connecting with the main filters. (1,024,082, Apr. 23, 1912.)

Lead and Copper.

Sintering Machine.—The sintering machines devised by Dwight and Lloyd have been constructed on the down-draft principle, as described and illustrated in our issue for February, 1912, page 87. In a patent recently granted to ARTHUR S. DWIGHT, of New York, a modification of the "straight-line" down-draft machine is proposed, in which an upward draft may be employed. The ore is deposited on an endless moving grate as in the down-draft machine, but the igniter is below the grate instead of above it, and the ore bed is held in the desired state of quiescence by means of a second endless moving grating in contact with the upper surface of the bed of ore. Upper and lower "wind boxes" house that part of the grate in which combustion and sintering is taking place, and a fan is provided to force air through the bed, or a suction fan may be used to draw the air in the desired direction. The invention may be applied also to stationary grates, with a perforated grate resting on the ore to prevent it from being disturbed by the blast. (1,021,509, Mar. 26, 1912.)

Alloys.

Substitute for Brass.—Mr. Louis Gross of Homestead, Pa., has been granted letters patent on a composition of matter made from 3 lbs. copper, 1½ oz. ash or clinker, and 1½ oz. borax.

The copper is heated to about 1000°F., when the powdered clinker and borax are added. The mass is then heated to about 1975°F., and afterward cast into molds. The cinder or clinker contains about 35 to 40 per cent metallic constituents, the effect of which is to harden the copper and make it a suitable substitute for brass. (1,023,642, Apr. 16, 1912.)

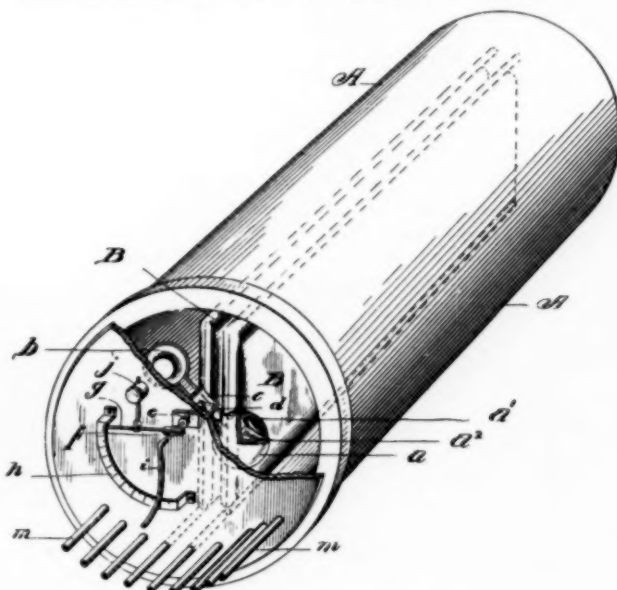


FIG. 3.—FILTER PRESS INDICATOR.

Pyrophoric Alloys.—Ferdinand Krieger, of Berlin, Germany, has compounded a new alloy of manganese and antimony which has pyrophoric properties. It is claimed that the formation of the spark is better than in the case of cerous iron, in that it gives a long flame instead of a cluster of sparks. Further, the new alloy is said not to disintegrate under the influence of the air. The alloys must contain more than 10 per cent each of manganese and antimony, and a good effect may be obtained by adding certain metals, such as chromium up to 20 per cent, but better less than 10 per cent; titanium up to 15 per cent, but better less than 8 per cent. A little magnesium or aluminium may be added to facilitate the process of alloying. (1,023,661, Apr. 16, 1912.)

The rare metals of the cerium group are used for a similar purpose by AUGUST LESMÜLLER, of Munich, Germany. Instead of using iron, nickel, etc., as hardening metals, he prefers to use silicon, titanium or boron, as these give harder alloys which are more economical in use. The amount of hard metal added must be within the following limits: Silicon, 1.8 to 14 per cent; boron, 1.2 to 8 per cent; titanium, 1.5 to 19 per cent. The more of these metals added to the cerium metals, the harder the alloy will be. (1,023,208, Apr. 16, 1912.)

Synopsis of Current Literature

Gold and Silver.

Testing Zinc Dust.—The growing use of zinc dust in the precipitation of cyanide solutions makes it desirable to have certain definite standard tests which may be applied to determine its fitness for metallurgical work. In the *Journal of the Chem. Met. & Min. Soc. of S. Africa*, for February, 1912, Mr. W. J. SHARWOOD, of the Homestake Mining Company, Lead, S. D., publishes some notes on testing zinc dust, and brings out the principal qualities which the material should have. These may be summarized as follows:

It should be dry and fine, nearly all—say, 95 per cent—should pass a 200-mesh screen, while very little—say not over 1 per cent or 2 per cent—should remain on a 100-mesh screen, and none on 50 or 60 mesh. It should not show signs of caking, or contain lumps which do not break up readily when shaken on a screen. An ash-gray color is more favorable than a decidedly blue or white, but color cannot be taken as an absolute criterion. The presence of a little lead—say, 2 per cent to 3 per cent—is an advantage. Laboratory tests with pure zinc, and with alloys containing up to 5 per cent lead, in the same state of subdivision, have invariably shown more rapid and more nearly complete precipitation in the case of the alloy. The presence of a little zinc oxide is not detrimental, although it diminishes the quantity of zinc metal present. Attempts to remove the oxide usually result in removing more or less zinc and sometimes in the destruction of the finest particles. No injurious effect has been traced to any cadmium present. The samples which have been tested and proved satisfactory have shown from 85 per cent to over 95 per cent metallic zinc, most of them containing over 90 per cent.

Typical Analyses of Zinc Dust.

| Number and Source | Metallic Zinc | Zinc Oxide Little | Lead | Iron, Cadmium, Carbon and Insoluble |
|-----------------------------------|---------------|-------------------|-------|-------------------------------------|
| 1 Belgian | 91.50 | 0.5 | 0.5 | .. |
| 2 Belgian | 88.74 | 6.60 | 2.5 | 2.1 |
| 3 Belgian | 79.16 | 11.26 | 1.9 | 7.2 |
| 4 Average Belgian..... | 84.50 | 9.3 | 1.6 | 4.0 |
| 5 Silesian | 84.50 | 4.9 | 4.3 | 6.2 |
| 6 Silesian | 88.50 | 7.4 | 2.0 | .. |
| 7 Silesian | .. | 88.2 | 4.0 | 3.0 (SO ₂ 4.1) |
| 8 American | 29.60 | 57.5 | Trace | Insol. 9.6 |
| 9 American, good quality | 96.00 | .. | .. | .. |
| 10 European, imported, good | 90.90 | 4.0 | 2.7 | .. |
| 11 European, imported, fair | 85.00 | .. | 2.0 | .. |
| 12 European, imported, fair | 94.60 | 3.7 | 0.2 | Iron 0.3 |
| 13 Used at Deloro, Canada | .. | 3 to 5 | 1.74 | .. |

Various authorities give the specific gravity of zinc as from 6.85 to 7.21; of zinc oxide from 5.6 to 5.78, and zinc carbonate 4.3 to 4.5. Samples of zinc dust have given results from 6.82 to about 7.0, while the material itself weighs from about 2 to 2.5 grains per cc, or about 120 to 155 lb. per cubic foot. No connection has been shown between the apparent density and the quality, but at least one "heavy" sample was found unsatisfactory.

It is highly desirable to avoid contact with moisture or moist air in the transportation and storage of zinc dust. In a shipment of casks of dust imported into Montana the percentage of zinc oxide varied in different casks and in different parts of the same cask. Portions near the staves of a cask assayed 10 per cent more oxide than a portion in the middle, and a lumpy portion from the bottom of one cask showed 39 per cent oxide.

Chemical Examination: Determination of Lead.—Moisten 10 grains dust with water, then add 200 cc water and stir well. Add 10 cc strong sulphuric acid, stir well and cover. Warm to 60 or 70 deg. C. and stir frequently. If action is slow at start, add one drop of very dilute platonic chloride. When it becomes slow add 10 cc more sulphuric acid and continue warming until nearly all zinc is dissolved. Decant solution onto a filter, wash by decantation several times with water, and pass through filter. Wash residue from filter back into the beaker and dissolve with a little nitric acid; wash into a casserole, add 5 to 6 cc strong sulphuric acid and evaporate to dense fumes. Finish the determination in the usual manner, titrating with ammonium molybdate solution.

Estimation of Zinc Oxide in Zinc Dust.—Solution required: 250 cc. water, 70 grains ammonium chloride, and 150 cc strong ammonia water. One gram of dust is shaken in a stout test tube with 25 cc of the prepared solution, using a piece of soft rubber packing as a stopper held in place by the thumb. Shake well for exactly 5 minutes, and throw the mixture onto a filter, washing well with hot water. Dilute the filtrate with

hot water to about 100 cc, add a drop of phenolphthalein, neutralize with HCl and then add 5 cc HCl in excess. Heat to 80 deg. C., and titrate with standard ferrocyanide. Zinc found in solution $\times 1.245$ = zinc oxide in 1 gram. The error due to solution of metallic zinc is negligible if only five minutes contact is allowed. Carbonate of zinc dissolves in the same way as the oxide.

Estimation of Total Zinc.—One gram of the dust is dissolved in dilute HCl and made up to 200 or 250 cc, from which 50 cc is taken for analysis. Add to this portion 5 cc strong HCl, and about 2 gr. ammonium chloride, dilute to about 200 cc and titrate with standard ferrocyanide in the usual manner.

Estimation of Metallic Zinc in Zinc Dust.—A number of methods can be applied for this determination.

I. Take the difference between the total zinc and the zinc as oxide.

II. Reduction of chromic acid by subjecting the dust to the action of potassium bichromate acidified with sulphuric acid. The bichromate should be in considerable excess of the calculated amount for the zinc used. The residual chromic acid is determined by titrating an amount equal to that originally taken, and the solution after the zinc has acted, either:

1. By means of KI, titrating the liberated iodine with thio-sulphate, or
2. By means of a standardized solution of ferrous sulphate, or
3. By adding an excess of standardized ferrous sulphate, and completing titration with standard bichromate.

III. Reduction of ferric chloride or sulphate, and titration of the ferrous salt with standard permanganate or bichromate.

IV. Reduction by zinc dust of a solution of iodine in potassium iodide, titrating the residual iodine with thiosulphate. This has given good results only on small quantities, say, 0.1 or 0.2 g.

Following are results obtained by these methods on a sample of zinc dust:

I. Metallic zinc by difference, 78.7 per cent. II. Metallic zinc by reduction of bichromate, (3) 79.6 per cent. III. Metallic zinc by reduction of ferric alum, 77.1 per cent. Whatever reduction method is used, the metallic zinc can be calculated thus: 1 cc N/10 standard solution = 0.00327 g zinc.

Determination of Precipitating Efficiency.—A solution of potassium silver cyanide is prepared by dissolving 10 gr. AgCN and 5 gr. "99 per cent" KCN in a little water, and diluting to 1000 cc. It is then adjusted by a little more AgCN or KCN until the solution shows from 0.12 per cent to 0.15 per cent free KCN by titration with standard AgNO₃, using a 10 cc or 20 cc sample with the addition of 1 cc 2 per cent KI and a slight excess of ammonia to give a sharp end-point.

Weigh out 0.5 g zinc dust, mix with a few cc water and then pour in 250 cc of the prepared solution, stirring vigorously. Continue stirring for five minutes and see that all lumps are broken. Stir every ten minutes for about two hours, then filter, wash the precipitate thoroughly, sprinkle with test lead, wrap the paper carefully around the mass, and scorify carefully with about 20 g test lead. Scorify for five minutes and then cupel at low temperature. Milligrams of silver obtained from 0.5 g zinc $\times 0.0606$ = percentage precipitating efficiency. This test gives conditions similar to those obtaining in practice. Satisfactory samples of dust usually show an efficiency of between 40 per cent and 60 per cent, and sometimes as low as 35 per cent—100 per cent being the standard calculated for the complete replacement of pure zinc by silver.

Mechanical Tests—Sizing Test.—Good samples of dust will show 95 to 98 per cent or more passing a 200-mesh screen, and not more than 1 per cent on 100 mesh.

Elutriation Test.—For the purpose of further studying the physical characteristics of the dust, it may be elutriated by a current of water of definite velocity causing the finest portion of the dust to be carried away from the coarsest. On examination under a microscope the latter will be found to be composed

of impurities, round particles or aggregates of zinc, and feathery or fern-like aggregates.

Surface Exposed by Zinc Dust.—The efficiency of this precipitant is due to the large surface exposed. To calculate

the exposed surface we may use the formula $\frac{2304}{gd}$, which

expresses the total surface exposed by 1 ton (2000 lb.) of any material in uniform grains—either cubes or spheres—when g is the specific gravity of the material and d is the length of a side of a cube or the diameter of a sphere expressed in inches. The specific gravity of zinc being nearly 7, and assuming the material to be in the form of spheres of d inch diameter, we

have, square feet of surface exposed by 1 lb. zinc dust = $\frac{0.165}{d}$

Thus the portion which will just pass a 200-mesh screen, $d = 0.003$ in., will expose only 55 sq. ft. per pound, while the material averaging only 0.0001 in. in diameter—which constitutes a considerable portion of the whole,—exposes 1650 sq. ft. per pound. It is interesting to compare this with zinc shavings, which expose from 45.8 to 84.3 sq. ft. per pound, according to the size of the shaving.

Air-Lifting of Slime Pulp.—The ordinary air-lift has much to recommend it as a means of handling slime pulp, especially in those cases where aeration is a benefit. In the *Mining Magazine* (London) for April, 1912, Mr. A. W. ALLEN presents some considerations of this device.

In the erection or working of an air-lift the following errors should be avoided:

1. Insufficient or excessive ratio of submergence to lift.
2. Lack of precautions providing for the intimate mixture of air and pulp at the lift intake.
3. The use of bends or elbows in the discharge pipe.
4. Unnecessary air pressure.
5. Excessive volume of air.
6. High velocity in the rising main.

When the submergence of the lift pipe in the pulp is insufficient to satisfy an efficient ratio, an excess of air will be necessary to perform the work. With an unnecessary submergence the air pressure required rises above the economical limit. Various ratios are in practice, but it has been shown by a number of investigators and operators that a submergence of from one and three-quarter times to twice the required lift is most efficient. When possible the depth of submergence should be maintained at a constant level, in order to keep the conditions favorable to efficient working.

Efficiency is largely dependent on the intimacy of the mixture of air and pulp at the beginning of lifting. The best arrangement to secure this effect is to have the air pipe perforated with a number of holes which are surrounded by a sleeve of rubber hose. A single air jet will suffice for lift pipes up to 6 in. diameter, but in larger installations it will be necessary to distribute the air over as large an area as possible.

The air pressure required to start the lift will depend on the submergence and the specific gravity of the pulp. If H is the submergence in feet, and S the specific gravity, then, theoretical gage pressure would be $0.434 \times H \times S$ pounds per square inch. In practice an increase of from 10 to 15 per cent will be found necessary.

The volume of air required per unit volume of fluid lifted is proportional to the height of the lift. In Professor Josse's tests, at Charlottenburg, an efficiency of 4.9 per cent of the indicated work in the compressor cylinder was obtained with a submergence ratio of 2:1, lifting 24.6 ft. by the use of compressed air at equivalent atmospheric volume of one and three-quarter times the volume of water lifted. At Preesal, Lancashire, Kelly obtained an efficiency of 38 per cent, lifting 11.3 ft with the use of a free volume of air in the ratio of 4.5 to 1 of water.

As shown above, the gage pressure necessary to work an air-lift is dependent on the submergence and the specific gravity of the pulp. The required pressure is, therefore, independent of altitude, and air-lifting is as economical at altitude as at sea-level; an extra cost for compression being balanced by the increased expansibility of the air when compressed. E. A. Rix gives the ratio of the volume of free air to volume of water as follows:

| Height of lift, ft. | Volume of free air, cu. ft. | Volume of water, cu. ft. |
|---------------------|-----------------------------|--------------------------|
| 20 | 1.5 to 2.0 | 1 |
| 20 to 50 | 2.0 to 3.0 | 1 |
| 50 to 100 | 3.0 to 4.0 | 1 |

It is generally conceded that the velocity of the mixture in the rising main should be as low as possible. As a rough guide it may be taken that the area of the lift pipe in square inches should not be much less than one half the number of cubic feet of pulp required to be lifted per minute. With pipes of constant diameter the velocity in the rising main increases from the base to the top, and under normal conditions the expansion of the air is responsible for doubling the initial velocity. An increase in the area of the rising main to counteract this increasing velocity has been suggested, and while it would be impracticable in most cases, it would seem that in Pachuca tanks an increase in area of central tube from bottom to top would obviate an unnecessary discharge velocity, insuring a better mixture of air and pulp, and allowing quieter conditions at the discharge.

The **Calumet & Hecla Co.**, of Michigan, will regrind the copper tailings previously discharged into Lake Linden by Hardinge regrinding mills. The plant will consist of two units, each unit containing thirty-two 8 ft. diameter Hardinge conical pebble mills.

The oxalate-permanganate method for the determination of copper associated with cadmium, arsenic, iron or lead, consists in precipitating copper as oxalate by adding 2 grains of oxalic acid to 55 c.c., or 4 grains oxalic acid to 100 c.c. of a 50 per cent acetic acid solution of a copper salt containing 5 to 10 per cent nitric acid. The copper oxalate is decomposed by H_2SO_4 and titrated with $KMnO_4$. H. L. Ward (*Amer. Jnl. Sci.*, May, 1912), gives results obtained in a long series of experiments, and concludes that the method may be used with satisfactory results.

Transvaal Gold Production.—The number of companies reporting to the Transvaal Chamber of Mines in February, 1912, was 67. The total quantity of ore milled during that period was 2,026,140 tons. There were 10,016 stamps in operation, with an average duty of 8.06 tons per 24 hours. Tube mills in commission numbered 263. The yield for the month was 703,866 fine ounces gold.

The American Zinc, Lead & Smelting Company is constructing a zinc smelter at Hillsboro, Ill., with a complete sulphuric acid plant, where they expect to treat 30,000 tons of ore per annum. The plant will be in operation some time this year. The development of the company's Tennessee property has progressed so far as to warrant the construction of a mill, and an increase in capital stock from 150,000 to 300,000 shares has been proposed to meet the financial demands for these new improvements.

Chilean Production of Nitrate.—The production during 1911 exceeded that of any previous year, reaching 54,784,271 quintals (Spanish quintal = 101.41 lb.). The price fell as low as \$1.66 gold per quintal in March, but advanced to \$1.94 in October. New works of a capacity of 18,000,000 per annum were begun last year and will be completed this year. Authority has been granted by the government to put more nitrate land on the market. Nitrate constitutes about 80 per cent of the exports of Chile, and supplies about 60 per cent of the revenue of the government.

Heavy-Duty Crushing Rolls.

Automatic Lateral Adjustment

By S. W. TRAYLOR.

The movement for good roads throughout all countries has in the last five years trebled the demand for stone crushing machinery, and the enormous increase in the use of concrete, calling for great quantities of crushed stone, has greatly increased machinery requirements.

So great has become the demand for crushed stone that the finer or "sand" product used in all concrete and in road building, has been difficult to obtain of suitable character in many localities.

It has been found generally more satisfactory, and sometimes most advisable, to use the fines or sands made by the general stone crushing plants.

It is usually necessary, however, to have more fines than are made ordinarily in stone crushing, and for this purpose suitable crushers or fine grinding machines have been sought. There are a great variety of such machines on the market, among which are the ball mills, the swing hammer mills, the so-called disc crushers, and others, none of which, however, have been entirely satisfactory for one reason or another, but mainly because of the great expense in the matter of upkeep.

It has long been recognized that the crushing roll would be admirably suited for fine grinding, being unquestionably the cheapest machine in up-keep, if the tires could be prevented from corrugating and made to wear down smoothly, as the corrugation of the tires greatly decreases the capacity of the mill and affects the uniformity of the size of the product, and if not remedied by removing the tire and turning it down soon incapacitates the roll entirely. The time lost in removing the tires for turning down or truing, as well as the loss of the metal in so doing, greatly shortening the life of the tire, makes the ordinary roll anything but satisfactory for such purposes.

Certain manufacturers, however, have given a great deal of thought and attention to the general improvement in the design and construction of rolls in the last few years, and it is believed that the modern roll described below, is thoroughly dependable for fine grinding to 16-mesh.

Modern rolls have also been greatly desired by the large metallurgical companies, especially for concentrating plants where medium or preliminary fine grinding is necessary, and it is a well known fact that a roll makes a more satisfactory product for successful concentration than any other style of pulverizing mill. The trouble has been, however, that most users of rolls have attempted to obtain a product much finer than was practicable to secure from the machine, as it is not practicable, from an economical standpoint, to attempt to grind finer than 16 mesh or 1 mm with a roll.

The improvements in the construction of the modern roll make it entirely safe to consider the use of rolls as a matter of economy, and where properly used and where the product is properly prepared before delivery to the rolls, they will grind down to 16 mesh, on the average run of ore or rock, at a less cost per ton than any other method.

To do this, however, the normal capacity of the roll must be maintained, and it is necessary that it be equipped with the automatic lateral adjusting mechanism, which will positively prevent the corrugating of the tires. This gives to the roll its full capacity at all times, and a roll so equipped will grind just as thoroughly when the tire is half worn down as when it is first placed in commission, and without its having been removed and turned down.

The working out of this automatic adjusting device has made it possible and practicable to increase the width of the face of the rolls, as with this arrangement there is no difficulty in preventing corrugation of the tire up to a width of 20 inches, and it is entirely possible to increase the width even beyond this.

Moreover, in fine grinding practice with rolls, there is no question but that a roll operated at a low peripheral speed will give far better results than a roll running at a high speed; and if the width of the face can be increased, the speed of the roll may be reduced and still maintain the capacity. A slow running roll is unquestionably more desirable from the standpoint of up-keep, as there is far less shock or jar on the bearings, frame and the machine generally than would be the case at a high speed. It is true that a roll running at a low speed requires more horsepower to operate the machine, but the horsepower per ton of product will be found to be very much less, as a slow running roll will produce from 25 to 40 per cent more fines than one with a high peripheral speed, and the economy is therefore apparent.

A careful study of the following description, with the accompanying cuts, of the automatic lateral adjustment will be of general interest, but of particular advantage to those who may be concerned with this important problem of fine grinding.

It will be noted that there is mounted on the end of the so-called stationary shaft a sleeve *F*, the shaft having been turned with flanges corresponding to the recesses in the sleeve. At the bottom of the sleeve is provided a U-shaped opening, through which passes an eccentric shaft *D*. The end of the roll shaft is turned down to receive an oil tempered forged steel worm wheel *A*; this worm wheel meshes into a gear *B*, which is operated as the shaft rotates, and on the shaft on which *B* is fixed, as shown in the plan *X*, there is provided a pinion gear, *H1*, which meshes into the large gear wheel *C1* mounted on the end of the eccentric shaft *D*.

Through this system of back gears, the eccentric shaft *D* makes one complete revolution to every 120 revolutions of the roll shaft, giving a slow reciprocating motion to the stationary roll, thus continually changing laterally the relation of the wearing faces of the roll tires.

Without the lateral adjustment the two tires would present exactly the same faces to each other at all times, and in running in this same position continually the roll tires would soon corrugate. To prevent this corrugation with the ordinary hand adjustment requires constant and careful attention on the part of the operator to see that the rolls are often and regularly shifted, and the greatest attention must be given to the feed of the roll.

With this automatic adjustment no particular attention is required. It is possible to utilize from 85 to 90 per cent of the steel in the tire for crushing purposes, and at all times the roll maintains its normal capacity.

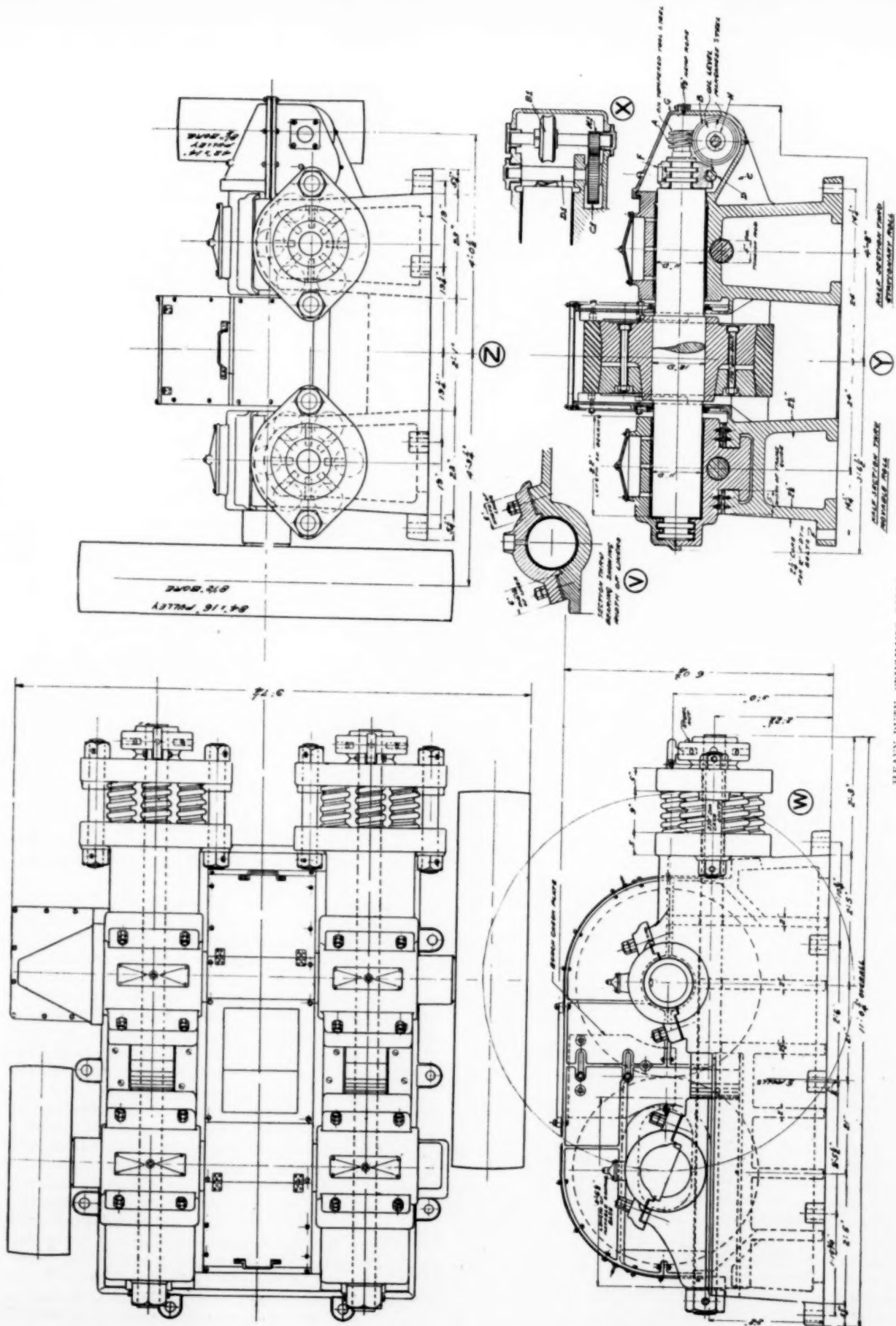
It will be noted that the lateral adjusting mechanism is completely housed, making it positively dust proof. The housing, being kept filled with oil, insures perfect lubrication of all the gears and reduces the wear to a minimum.

Cut *Z* shows the end elevation of the roll, and cut *W* the side elevation. Cut *V* shows the section through one of the bearings, which are of very heavy construction, machine finished, with ample width for liners, packed in the ends and protected at the upper side by a projecting lip, and are dust proof.

Attention is also called to the fact that there are no collars of any sort on the roll shafts, which have been found to be a great nuisance, as they are difficult to hold securely to the shaft and become dangerous. This feature alone, in the machine herein described, will be found of value and considered of importance by the practical operator.

It will be noted also that all moving parts, such as the guides shown in the section, cut *Y*, are faced with oil hardened machine steel, this being a point that usually shows heavy wear in rolls subjected to continuous hard use.

The cuts here shown represent a roll 42 inches in diameter by 16-in. face, which is the heaviest machine of this size that has ever been built. This roll is intended for especially heavy service, where fine grinding is required, with very large capacity. In fact, this roll has, easily, 50 per cent greater capacity



HEAVY-DUTY CRUSHING ROLLS.

than rolls of similar diameter and width of standard construction. The weight of this machine is 53,000 lb., while the standard roll of the same size weighs 28,000 to 36,000 lb.

This particular roll was designed specially and is being built for use in connection with the large metallurgical plant of the Miami Copper Co. at Miami, Arizona.

By careful examination of these cuts, it will be noted that the greatest attention has been given to the matter of lubrication. Much consideration has also been given to the size of the roll shafts, tension rods, cage and heart bolts, as well as to the length of the base of the movable bearing, and by comparison with any standard roll, it will be seen that they have been greatly increased in size.

These machines are built by the Traylor Engineering & Manufacturing Company in three types, viz.: AA, A and B, the main difference being in the weight of the machine suitable for different classes of work and have been recently furnished to other large companies, among which are the St. Louis Smelting & Refining Co., the Butte & Superior Copper Co., the International Pavement Co., the Kennicott Mines Co., the Canada Iron Corporation and the Virginia Graphite Co.

Combined Potash Bulb and Drying Tube

BY GEORGE P. VANIER

The Arthur H. Thomas Company, of Philadelphia, has recently placed on the market a new combustion train with an electric furnace, the principal feature of which is the Vanier combined potash bulb and drying tube. Since the direct combustion of steels in oxygen has come into general use, chemists have been unable to find a potash bulb on the market suitable in every way for this method.

It is desirable to have a combined potash bulb and drying tube, the inlet and outlet of which can be closed to prevent diffusion of oxygen while weighing. They should allow the gases to pass through them rapidly without loss of CO_2 or moisture and should have a large absorbing capacity. Several months' exclusive use of the above combined potash bulbs and drying tube in a large steel works laboratory has shown them eminently suited for the work.

The advantages of these bulbs are:

Their large capacity—six grams or more of CO_2 can be absorbed, thus enabling one to make 100 or more combustions without refilling.

When weighing with the bulbs filled with oxygen no rubber caps are necessary as the glass stopcock closes the inlet and outlet while weighing.

They are strong, compact and more easily handled and less liable to be broken than the ordinary bulbs with drying tube attached.

They present a smooth outer surface which is easily kept clean.

They present a minimum outer surface for moisture condensation.

They are self-supporting and offer a firm base when placed on the balance pan for weighing.

As the drying tube is vertical and the moist gases pass in at the bottom the drying tube seldom stops up. As the solid caustic potash deliquesces it forms a pool and extra seal in the bottom of the drying tube.

Each bubble of gas comes in contact with a fresh portion of the KOH solution, and is in contact with the KOH solution while the bubble of gas passes through ten inches of glass spiral tube. The gases can be passed at a high rate without any fear of loss of CO_2 or moisture.

When the gases are passing through rapidly the action is perfectly quiet; there is no jumping or spraying of the solution.



VANIER POTASH BULB.

To fill, remove stopper and glass stopcock. Fill drying tube to base of bulb with dry solid caustic potash (through 5 and on 10 mesh). Finish filling drying tube with dry caustic potash (through 10 and on 20 mesh). Place a small wad of cotton or glass wool on top. Through side stopper, with the aid of a small funnel, pour a solution of caustic potash (1 lb. caustic potash to 600 c.c. water) until it reaches the top of the coil. Grease and replace stopper and stopcock.

To empty, remove stopper, stopcock and wad of glass wool. Slip a piece of 1/4-inch rubber tubing, about 10 inches long, over side tubulature. Turn bulbs upside down, holding in left hand, and with right hand grasp end of rubber tubing and hold end under a tap of running water, thus allowing bulbs to fill with water. Now lower end of rubber tubing, allowing water to run out. Repeat this operation of filling and emptying several times. Drain and dry, when bulbs will be ready for refilling. The bulbs charged weigh between 140 and 150 grams.

Pennsylvania Steel Co., Steelton, Pa.

Cement Grinding.

BY L. H. STURTEVANT.

Increased competition in the cement business is causing the manufacturer to use every endeavor to reduce the cost of manufacture. Naturally one of the first matters to receive his attention is the grinding machinery, as this forms such an important part of a cement plant. Since, in fact, it often determines a profit or a loss to the whole business, it deserves most intelligent investigation.

Five important elements enter into the cost of grinding cement materials:

- 1—Cost of grinding machinery.
- 2—Power to operate.
- 3—Wear and tear (upkeep).
- 4—Production (output).
- 5—Continuous operation (absence of shut-downs).

In other words, the cost of producing finished cement per barrel per hour in the grinding mills covers all of these items and the cheapest method of producing this result is the aim of every cement manufacturer.

Large units have come to stay, for the cement business is one of large proportions and the use of many small individual machines is becoming obsolete, and rightly so, for who will install ten small grinders when two large ones will do the work?

It is acknowledged by experienced cement engineers that with any of the small machines now in use it requires from 6 to 10 horsepower per hour per barrel to reduce Portland cement clinker to a finish; that the wear and tear is from \$800 to \$1,800 per year per grinding mill (tube mills excepted).

The above figures are only for clinker. As to the cost of grinding limestone, coal, shale and clay, while the upkeep cost is not so great, yet the power is practically the same.

Now if a large unit can produce the same results with one-half the power and at one-half the cost for upkeep, one can readily appreciate the reason for its adoption.

The Sturtevant cement unit does all this, and more, for it opens up new possibilities for the cement manufacturer. It not only lessens materially the cost of his finished product, thus making large savings in all of his grinding departments, but lessens labor, cheapens buildings, because of the small space occupied for large outputs, simplifies and unifies the entire plant. It ensures continuous operation by practically eliminating breakdowns and by its few and accessible parts the time required for replacement is only a small fraction of that necessary with even the smallest machines.

This unit consists (as shown in Fig. 1) of a giant duplex ring-roll mill, an elevator, two Newaygo separators and one tube mill.

This is a simple, compact arrangement for clinker, limestone or coal, and has enormous capacity.

The giant ring-roll is used in combination with a tube mill for two reasons:

First—Because no single machine can do two kinds of work with equal efficiency; i.e., it is either better as a preliminary grinder than as a finisher, or vice versa.

No mill having internal screens can be as efficient as a mill that is free to grind and discharge its finished product the instant it is made.

It has proved a physical impossibility to make internal screens of sufficient size or give them proper vibration to handle the product of any good grinder. The result is that much of the sufficiently ground material cannot escape, which cushions and thus cripples the grinding action of the machine, lowering its efficiency and causing much useless wear and tear and bearing trouble due to excessive confined dust.

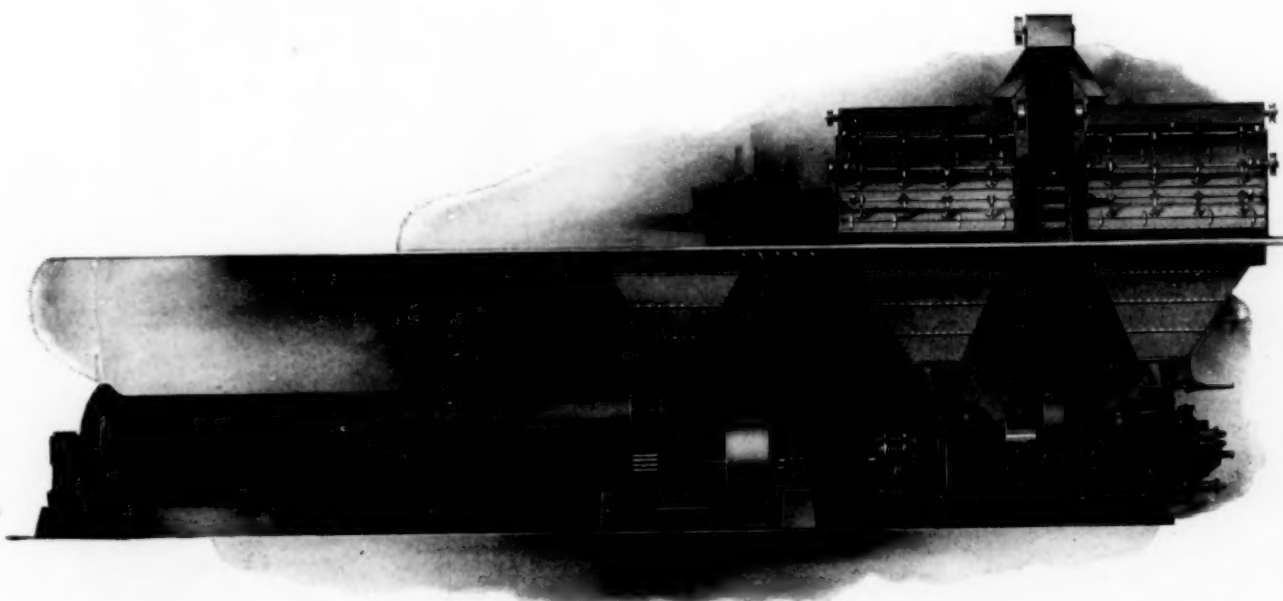
Properly used, the tube mill is a big unit with no small parts to give trouble—and it is a continuous operator.

Even the power is in its favor instead of against it, as most people think. Grinding with a 20-mesh feed, it does unquestionably take too much power for its output, i.e., 75 hp. is needed to drive a 5 x 22 mill to get from it only 12 to 15 barrels per hour (corresponding to approximately 7 hp. per barrel per hour).

But with that same 75 hp. and feeding the tube with 40-mesh clinker, we will get 30 barrels per hour, instead of 12 to 15 barrels, as before (that is now only approximately 2½ hp. per barrel per hour).

Now, again, taking the same mill, same power, and giving it an 80-mesh feed, the results will be a revelation. It now produces from 40 to 55 barrels per hour (or approximately 1½ hp. per barrel per hour).

Let us see next what can be expected from a unit, properly



CEMENT GRINDING UNIT.

By removing the screens from ball and other mills tests have proved the mill efficiency was increased by as much as 33 1-3 per cent.

Again, it is never economical to either screen or air-separate a finished product as fine as cement. It is too delicate an operation; it takes too much space and power, and it is complicated. Screening coarse material is easy, but with dust of cement fineness it is impractical on a large scale.

The ring-roll can finish, and some manufacturers would sell it for such work, but we would rather use it in just the place for which it is best adapted, and if there ever was an ideal preliminary grinder, the ring-roll is the machine.

On 20-mesh grinding, taking clinker 1½-in. size, its output is from 80 to 130 barrels per hour. On 40-mesh work, 60 to 80 barrels. On 80-mesh grinding, 40 to 60 barrels per hour. All of this is accomplished with 80 hp.

When a preliminary grinder will do such work as that why try to make it finish or do something that no grinder of its class should be asked to do, and hamper it with internal screens that hold in material already reduced, and clog and render the grinding members ineffective?

Second—Why do we recommend a tube mill as a finisher when we do not build them and have no interest whatever in tube mills?

Because the tube mill properly used is just as ideal a finisher as the ring-roll is as a preparatory grinder.

arranged, on a scientific basis, where screens are used, but in their proper place; and each machine operated in a highly specialized manner, never allowing either to do anything except just that work for which its proved adaptability cannot be questioned.

Plant:—

1—No. 2 Duplex ring-roll mill, taking 1½" to 2" clinker and grinding to 80-mesh. Capacity 40 to 60 barrels per hour. Power 80 to 90 hp.

2—No. 3 Newaygo screens. To take out the 80-mesh material from the ring-roll product. Comparatively coarse screening and 100 sq. ft. of efficiently vibrated 40-mesh wire cloth to do the work. Power 1 hp. each.

1—6 x 18 tube mill. To take the screened 80-mesh ground clinker from the ring-roll and Newaygo screens and reducing it to a finish, 98%, 100 and 85% 200-mesh. Capacity 40 to 60 barrels per hour. Power 75 to 85 hp.

Thus it will be seen we have a unit of 900 to 1500 barrels output per day, with a power expenditure of approximately 3½ hp. per barrel per hour.

This is the largest unit of its type and yet is as accessible and as elastic as any plant of small individual machines which is full of complications, and a complete machine shop is necessary to keep it going.

The above Sturtevant unit has been criticized by some men who have given the matter no thought, on the ground that it is

too big, too unwieldy. They say if something goes wrong the whole plant is shut down.

Let us see if this is true.

The ring-roll mill of duplex design has each half absolutely independent of the other—one half may be operated while the other half is at rest or is stopped for repairs. This feature enables the operator to reduce the workable size of the unit by half.

Again, what is there to get out of order or repair on the ring-roll? If we look it over, there are no scrapers, pushers, plows, guides, screens, shields, balls or other parts of a nature needing constant renewal as in other mills.

If we open the door, a matter of ten minutes, we will find a large ring or tire and three rolls, and that is all the parts we can find that come in grinding contact with the material being ground.

This explains why there is practically so little wear. Because there are no other parts in these mills that come in contact with any material to cause wear.

Is it likely that the upkeep can be much under these conditions?

Only the ring and three roll shells need to be looked after. These parts are *thick* and hard and last a long time, because the ring runs at only 64 revolutions per minute and the rolls have exactly the same surface speed, and when they need replacements it is the work of only *minutes* instead of hours to "open the door" and put new rolls on.

Ring-rolls are continuous runners.

Next, an elevator and two Newaygo screens are to be looked out for. But an elevator is needed in any case, usually *several*, plus conveyor systems that are needed for a multitude of small units; therefore, one elevator for a single great producer is not a complication.

Newaygo screens are continuous runners too, for while the small parts of one screen wear out, yet duplicate parts may be easily and cheaply kept on hand, so there is no delay in the whole system or stoppage, while necessary changes are made in one screen.

It is to be borne in mind that this is a comparatively *coarse screening system* and is therefore easy, for the separators have a great capacity on coarse work, and the *large wire* used for coarse screening renders them *durable*.

The tube mill is the only machine left and is too well known to require description. Everyone knows its interior parts consist of linings, replaceable once a season, and pebbles which may be replenished at intervals through the manhole. It is evident the tube mill is a continuous runner.

Shut-downs are expensive for a cement plant particularly, that ought to be relied on to operate continuously. This point is appreciated by every manufacturer. The Sturtevant unit is bound to be a continuous runner.

The cost of the Sturtevant unit is less than any other per barrel of production per hour, a whole lot cheaper:

The power is less, much less.

The upkeep is many thousands of dollars less, because it requires so few replacements.

Buildings are cheaper, for they may be smaller for a compact unit.

In fact, no feature of this plant can be mentioned that is not better in theory and in practice than any other.

Cement manufacturers are appreciating this fact and are keeping the Sturtevant Mill Co. of Boston, Mass., busy building ring-roll mills to meet the demand for big, economical grinding units.

The Colorado production of zinc now exceeds in value that of silver or of lead, and ranks next to gold. Improved methods of ore dressing are largely responsible for this condition. The value of the zinc output in 1910 was \$3,366,437, while in 1911 it rose to \$5,696,189. A further increase may be expected in 1912 owing to electrostatic methods of separation.

New Apparatus for Gas Analysis.

One of the most interesting papers presented before the Division of Industrial Chemists and Chemical Engineers at the Washington meeting of the American Chemical Society (December, 1911) dealt with some important improvements in apparatus for gas analysis, which combine in providing surprisingly greater convenience, portability, accuracy and rapidity and a minimum liability to breakage.

Mr. F. M. WILLIAMS, the author of that paper, is himself the originator of the new improved gas analysis apparatus, which he developed in his research and industrial laboratories in Watertown, N. Y. The paper is herewith given practically in full:

Probably the best known and most widely used apparatus for gas analysis is that of Orsat, or one of its many modified forms. The numerous modifications which have appeared from time to

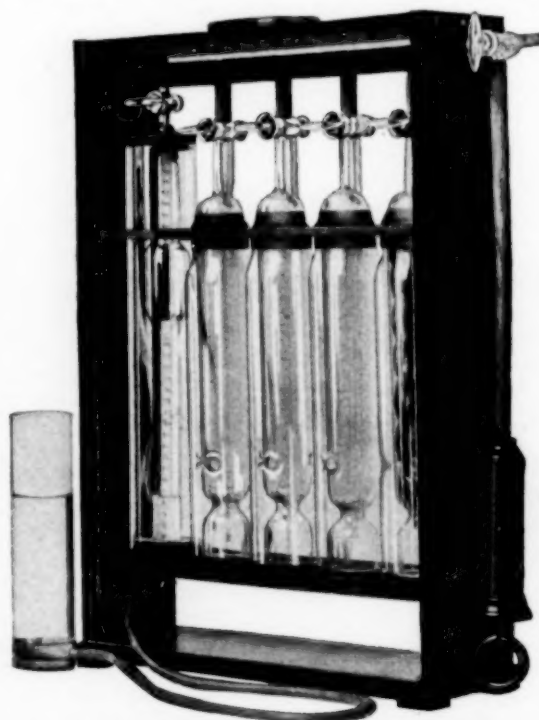


FIG. 1.—OUTSIDE VIEW OF GAS ANALYSIS APPARATUS.

time bespeak a high tribute to the general utility of this instrument and also a keen desire to remedy its shortcomings.

The faults in the original Orsat apparatus may be briefly summarized as follows:

First, although portable, it is much too bulky. Mr. Williams has found that its size may be reduced nearly 50 per cent., still retaining the 100 cc. measuring burette and without impairing accuracy at any other point.

Second, the original form is awkward in manipulation, due to the position of the burette on the right-hand side, necessitating either left-handed manipulation or crossing the hands in the line of vision while operating.

Third, the design of its absorption pipettes with U-tube or gooseneck reservoir, is particularly fragile and liable to breakage at the bend, with the attendant unpleasant deluge of highly concentrated caustic solutions.

This form of pipette is difficult to wash and refill and is also slow in its absorption of gas.

In the modifications which Mr. Williams has developed the above noted objections have been overcome.

First, there is a marked reduction in size. Mr. Williams' model "A," arranged for the complete analysis of combustible gases, occupies a space of only 12 x 4 x 17½ inches, while the flue-gas apparatus, model "B," is only 9½ x 4 x 17½ inches.

The measuring burette is placed at the left side, allowing freedom of the right hand in manipulating stop-cocks, etc.

A special design of explosion burette is indicated in Fig. 2, with terminals permanently connected to binding-posts on outside of case. The bulb is placed lower upon the tube, permitting

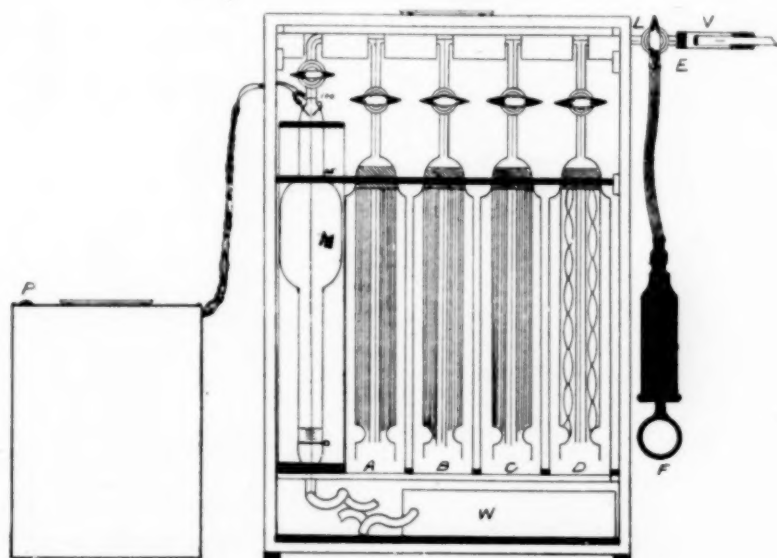


FIG. 2.—MODEL A GAS ANALYSIS APPARATUS FOR COMPLETE ANALYSIS OF COMBUSTIBLE GASES, CARBON DIOXIDE, ILLUMINANTS, OXYGEN, CARBON MONOXIDE, HYDROGEN, METHANE, AND NITROGEN.

15 cc. of clear graduation to be read on the small caliber of the burette above the swell.

The next point to be noted is the absorption pipette, of which two forms are shown, the simple and the bubbling, either form slipping interchangeably into the pipette jar or solution reservoir, with the closure at the top effected by an inexpensive rubber band.

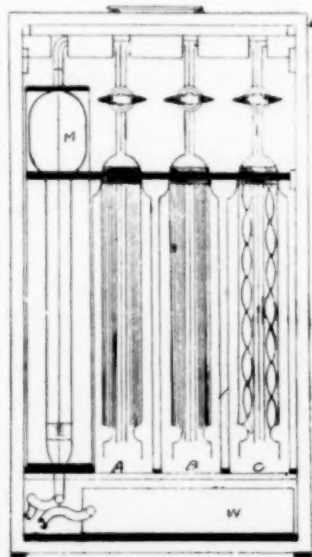


FIG. 3.—MODEL B FOR FLUE GAS ANALYSIS—CARBON DIOXIDE, OXYGEN, CARBON MONOXIDE.

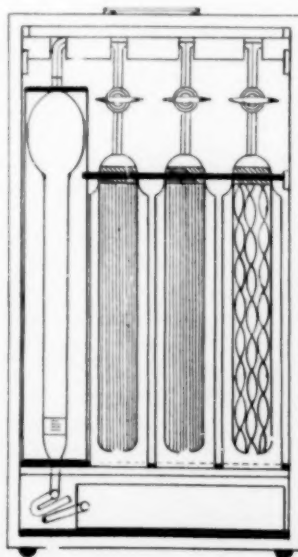


FIG. 4.—MODEL C FOR FLUE GAS ANALYSIS—CARBON DIOXIDE, OXYGEN, CARBON MONOXIDE.

Both forms are so constructed as to prevent the thin glass tubes from falling out when the pipette is removed from the jar.

The simple pipette needs little comment.

The bubbling pipette, which is exceedingly rapid in absorption, owes its high efficiency to the fact that the gas is not only caused to bubble through a long column of liquid, but the bubbles are also finely broken up by the thin glass tubes with which the pipette is filled and a large absorption area is presented by the wet surface of these tubes.

While the arrangement at the top of this pipette somewhat resembles that of Babb, this difference is to be noted—in the original Babb the long capillary tube which passes to the bottom of the pipette enters at the center or highest point while in the form here presented the long tube enters at the side, allowing the short capillary, through which the liquid is brought up to the reference mark, to be placed at the highest point, thereby completely removing bubbles from the surface of the liquid.

The mounting of the glassware in the case is such as to render all parts accessible and instantly removable for cleaning or recharging. The T's at the top are held in a channel piece, G, resting in saddles. The front-half of the cross-piece, H, is removable by lifting from the supporting saddles at the sides of the case.

The exposed portions of the inside of the case are rubber-covered.

The detachable three-way T stop-cock, with hard rubber pump and valves shown in Fig. 2, makes it possible to take a dry sample of gas directly from the source of supply, eliminating the inaccuracy and bother of collection over water, transference, etc.

After connection with supply the pump is operated, discarding the gas in the connecting line until the fresh sample is brought up to the apparatus, when by turning the stop-cock and

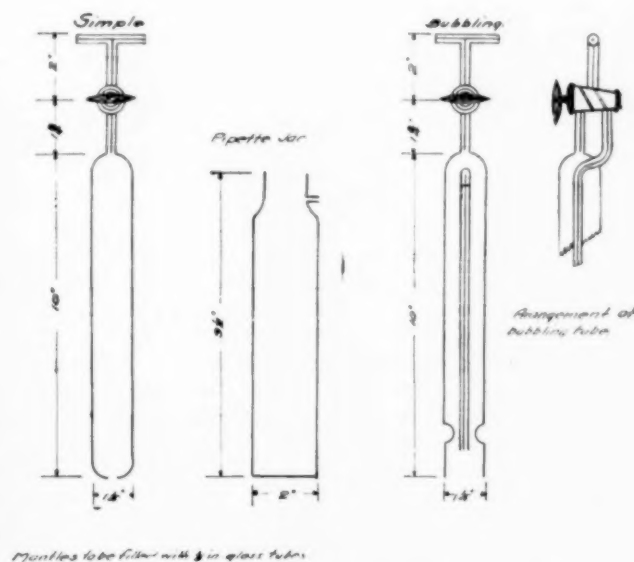


FIG. 5.—PIPETTE DETAILS.

lowering the water-level bottle the measured sample is taken directly into the burette.

This feature is especially advantageous in flue-gas analysis, when the apparatus may be permanently housed in the boiler-room with a line of piping running to the flues enabling an accurate determination of firing conditions to be quickly made at any time. The introduction of an aspirator tank into the line also enables an average sample to be taken covering any desired period of time. This method of control has some advan-

tages, at least, over a recording CO₂ instrument, in that its accuracy and adjustment are unquestionable and we are also able to determine carbon monoxide, which is sometimes an important factor.

Mr. Williams concluded his paper by the statement that years of experience with various kinds of gas apparatus warrants the statement that the form here described is without an equal in the combination of convenience, accuracy, rapidity and minimum liability to breakage.

Personal

Mr. Harold O. Bosworth, formerly of the Denver Fire Clay Company, and later manager of the assay department of the Mine & Smelter Supply Company, Denver, Colo., has gone to Allentown, Pa., where he will manage a concern manufacturing vitrified brick.

Mr. J. R. Finlay delivered the commencement address at the Missouri School of Mines, Rolla, Mo., May 31.

Dr. Hans Goldschmidt, the famous inventor of the electrolytic detinning process and of the thermit process, is at present in this country. He is accompanied by two of his daughters. He expects to return to Europe in the middle of June.

Mr. Victor G. Hills has returned to Denver after spending about one year in Nova Scotia, where he was engaged in the development of a tungsten property and the erection of a mill for the treatment of scheelite.

Mr. Joseph Hodgson, of Ishpeming, Mich., has been appointed superintendent of the Copper Queen mine, Bisbee, Ariz.

Messrs. L. D. Huntoon, B. Stoughton and A. H. Elliott have offices at 165 Broadway, New York, and will engage in practice as chemical, metallurgical and mining engineers.

Prof. W. S. Landis, associate professor of metallurgy, Lehigh University, and assistant secretary of the American Electrochemical Society, has resigned and taken the position of technologist to the American Cyanamid Company.

Mr. E. P. Mathewson, general manager of the Anaconda Copper Mining Company, was awarded a gold medal by the Institution of Mining and Metallurgy, London, in recognition of his eminent services in the advancement of metallurgy, and particularly the metallurgy of copper.

Mr. J. W. D. Moodie, formerly general manager of the Yampa Smelting Company, Utah, has resigned that position and accepted a similar position with the Britannia Copper Syndicate, Ltd., Britannia Beach, British Columbia.

Mr. John Jermain Porter has resigned from the University of Cincinnati and after June 1st will devote his entire time to consulting practice as metallurgical engineer. Mr. Porter will make his headquarters at Staunton, Va., and will give especial attention to improving the operating efficiency of blast furnace, foundry, coking and other processes. In this work he will be associated with Mr. Charles Catlett, Consulting Economic Geologist of Staunton, Va., whose strong connections with the Southern iron industry are well known.

Mr. E. P. Post, assistant in chemical department of the Carnegie Tech, Pittsburgh, has been appointed chief chemist of the Enameled Pipe & Engineering Company, Elyria, Ohio.

Mr. W. S. Quigley, who has been Vice-President and General Manager of the Rockwell Furnace Company, severed his connections with that company recently and has formed the Quigley Furnace & Foundry Company. Mr. Quigley has associated with him able furnace engineers with the intention of carrying on advanced ideas in furnace construction. The Quigley Furnace & Foundry Company is a Massachusetts corporation with a plant at Springfield, Mass. Ground has already been purchased for an enlargement of their plant.

Messrs. W. C. J. Rambo and L. G. E. Bignell have formed a partnership to engage in mining and metallurgical engineering. Their office is at 923 First National Bank Building, Denver, Col.

Messrs. Ricketts and Banks have removed their offices and laboratories to 80 Maiden Lane, New York.

Mr. G. A. Roush, a graduate of Indiana University and post-graduate in chemical engineering at the University of Wisconsin, has severed his connection with the West Virginia Agricultural Experiment Station, as research chemist, to accept the assistant professorship of metallurgy in Lehigh University, under Prof. Jos. W. Richards.

Mr. Fred G. Schenkel has associated himself with the sales force of the Treadwell Engineering Company, Easton, Pa., and will specialize their line of electric steel castings. Mr. Schenkel was formerly connected with the Hess Steel Casting Company.

Mr. R. J. Wysor has been appointed chief chemist of the Bethlehem Steel Company, succeeding Mr. Robert C. Kresge, resigned.

BOOK REVIEWS.

Laboratory Exercises in Physical Chemistry by J. N. Pring, D. Sc. 5 x 7½ inches (12½ x 19 cm.). 163 pages, 27 illustrations, Manchester, England: University Press.

Only the main topics are selected, and these particularly in the line of electrochemistry. The chapters are on molecular weight determinations, calorimetry, electrochemistry, electrolytic preparations and pyrometry. The book is elementary, for beginners, but appears well suited for this class. The calorimeter connections are rather crudely applied, and we wish our English friends would abandon the name voltameter for the instrument which measures coulombs and for which Theo. W. Richards has proposed the significant term "coulometer."

Aside from minor blemishes, it is a commendable book for the purpose intended.

Die elektrochemischen Verfahren der chemischen Gross-Industrie. Ihre Prinzipien und ihre Ausführung. Volume 2: Elektrolysen mit unlöslichen Anoden ohne Metallabscheidung. By Dr. Jean Billiter. 17 x 24 centimeters, 535 pages, 53 tables, 228 cuts. Price 28.50 marks. Halle: Wilhelm Knapp.

Volume 1, by the same author, covered the separation of metals from solutions and was reviewed (not very favorably) in this journal, September, 1909, page 414. Volume 3 is to be on the electrolysis of molten salts, and Vol. 4 on electric furnaces.

This volume covers a highly interesting and important field in a very satisfactory manner. The electrolysis of water is given 108 pages, while the electrolysis of alkali chloride solutions takes 322 pages, the bulk of the book. In this latest chapter the author is thoroughly at home, and moves systematically and thoroughly through the whole of this great subject, dividing it into (a) chlorine and alkali; (b) hypochlorite and electrical bleach; (c) electrolytic chlorates and perchlorates.

Everyone interested in these processes or industries should get this book.

A third chapter treats briefly of the electrolysis of bromide solutions.

An appendix of over 50 pages brings the various subjects treated in Volume 1 up to date, giving supplementary recent information on the electrolytic separation of copper, silver, gold, lead, zinc, tin, nickel, antimony and iron.

Without any question this is a praiseworthy book, written more carefully and with much better command of the subject matter than Vol. 1.